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STUDY TERRESTRIAL APPLICATIONS
OF
SOLAR CELL POWERED SYSTEMS

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16. Abstract <p>A study was initiated to search out, list and evaluate terrestrial applications of solar cells and design systems for those applications that show the most promise for becoming practical and accepted by users within the next five years.</p> <p>The study includes the definition, categorization, evaluation and screening of the most attractive potential terrestrial applications for solar cells. Analysis of markets with high growth rate and large volumes is most likely to reveal candidates that would accept new product and system concepts. Potential markets are initially grouped and categorized in a general sense and are weighted in priority by their business volume, present and future. From a categorized list including marine, transportation, security, communication, meteorological and others, 66 potential solar cell applications have been cataloged.</p> <p>A methodology was formulated to include the criteria for evaluation and screening. The evaluation process covers all parts and components of the complete system required for each application and gives consideration to all factors, such as engineering, economic, production, marketing and other factors that may have an influence on the acceptance of the system by potential users. From the list of potential solar cell applications, ten applications were selected for further study. A brief description of each of the ten recommended applications is included, along with its function, requirements, advantages, disadvantages and an estimate of the performance of the overall system. Preliminary dimensional and weight specification and anticipated production volume and unit cost of the systems are also included. The study culminated in a detailed engineering design of systems to fulfill the two most attractive applications.</p>		
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INTRODUCTION

Silicon solar cells have been reliably used for electrical power in space applications from the beginning of the space program. Because of the high reliability and long active life required for the space program the silicon solar cells, in combination with batteries, have been the mainstay of most spacecraft applications.

However, solar cells are expensive. One major way to reduce their cost is to automate production. Unfortunately, the space market is not large enough to justify the necessary investment. The market can grow sufficiently only if terrestrial applications are found. But, the high cost of solar cells has been a general deterrent to the consideration of solar cells on earth. However, there may well be many applications where the initial cost of the solar cells would be overridden by the benefits offered by a self-contained, long-lived, maintenance-free, pollution-free, and quiet solar cell and battery power source.

This is the final report that will be prepared under NASA-Lewis Research Center Contract NAS 3-16828 awarded to Heliotek, Division of Textron on October 27, 1972. The contract calls for a nine-month study of terrestrial applications for solar cell powered systems. The study is structured into the following tasks:

- I Methodology
- II Cataloging of Candidates
- III Preliminary Evaluation and Screening
- IV Conceptual Design Study
- V Final Evaluation
- VI Detailed Design

The purpose of this contract is to search out, list, and evaluate terrestrial applications of solar cells and to design systems for those applications that show most promise for becoming practical and accepted by users within the next five years.

This study effort shall cover the definition, categorization, evaluation, and screening of the most attractive of potential terrestrial applications for solar cells that may become practical within five years. The formulation of a methodology, including the criteria for the evaluation and screening is part of this effort. The evaluation shall cover all the parts and components of the system required for each application and shall give consideration to all factors, such as engineering, economic, commercial, and other factors that might influence the acceptance of the system by potential users. The study will culminate with the engineering design of the systems to fulfill the most attractive applications.

Sections 1.0 through 6.0 of this volume provide a summary of the work performed under the above tasks set forth in the Statement of Work. Section 7.0 presents our conclusions and recommendations.

1.0 METHODOLOGY

1.1 General

The methodology used in this study to perform the systematic cataloging evaluation and screening of potential solar cell applications is based on proven successful methods employed previously. The methods outlined in this plan have resulted in product and system applications that were extensions of high technology research.

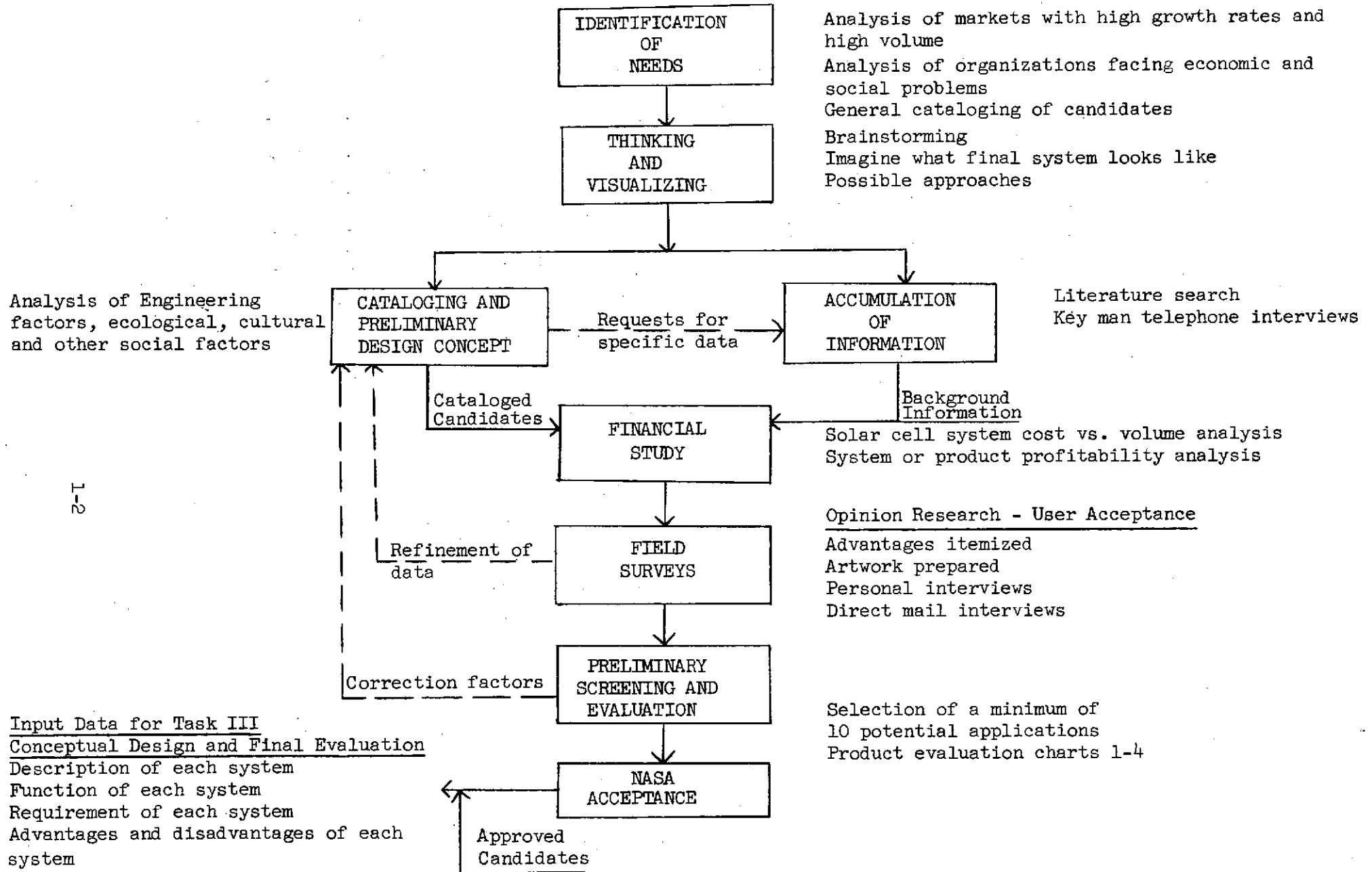
At the outset, two broad categories of products and systems are established. They are: (1) systems with relatively short range applications that could be practically implemented within five years, and (2) long range applications received the major concentrated effort. However, during the course of study, the second category of long range applications were cataloged for future reference.

The basic plan for the cataloging of candidates, preliminary evaluation and screening is shown in the Methodology Flow Diagram. This plan outlines a method that permits numerous potential applications to be screened with a minimum investment in time and effort.

1.2 Identification Of Needs

The first step in following the plan is to identify the needs of the marketplace. Analysis of markets with high growth rates and large volumes is most likely to reveal candidates that would accept new product and system concepts. This type of market can generally support an initial capital investment with a reasonable pay-back period. The industrial and residential security market is an example of such a rapidly growing marketplace. Another example of a market worthy of analysis are those industries facing economic and social problems. The electric power utilities are likely candidates for consideration in this area because of the increasing demands for electrical energy. Ecology factors, peak power supply demands and catastrophic system failures have created the need for new systems.

METHODOLOGY FLOW DIAGRAM



The communications industry also represents an excellent candidate for solar cell applications. Initial research by the Bell Telephone Laboratories was directed toward the use of solar cells to power communication links, but the electronics at that time required substantial amounts of power. Recent developments in solid state electronics using low power integrated circuits, MOS components and similar devices have opened a complete new realm of possibilities for the use of solar cell powered systems.

The potential markets are initially grouped and categorized in a general sense and are weighted in priority by their business volume, present and future. Following is an example of how these categories might be listed:

- (1) Marine Market
- (2) Security Market
- (3) Communications
- (4) Large Scale Power Generation
- (5) Consumer Product Market
- (6) Auxiliary Power and Peak Overload Equipment Market
- (7) Safety Equipment Market
- (8) Food Processing Industry
- (9) Automotive Industry
- (10) Commercial Transportation Industry
- (11) Petroleum and Chemical Processing Industry
- (12) Forestry and Conservation
- (13) Leisure Time and Recreation Market
- (14) Construction Industry - Solar House System

The industries thought to have needs requiring solar cell systems are then studied in order to determine what approaches are possible or most feasible. This process is accomplished during the Thinking and Visualization step.

1.3 Cataloging And Development Of Preliminary Conceptual System Designs

Visualized system and product concepts are processed in parallel with the Accumulation of Information step so that preliminary conceptual system designs can be firmed up while information is being gathered.

The preliminary conceptual designs are based on engineering, commercial and social factors. The factors considered during this step are:

- (1) Performance in relation to competitive approaches
- (2) Form factors (size, weight)
- (3) Service and maintenance
- (4) Life expectancy
- (5) Overall efficiency
- (6) Technical risks
- (7) Material availability
- (8) Availability of other system components
- (9) Availability of suitable production equipment
- (10) Production risks
- (11) Social impact of the system (ecology, cultural acceptance, etc.)

During this preliminary conceptual design step, the system concepts are updated by means of refinements in data inputs from field surveys and correction factors from the screening and evaluation process. Specific data is continuously requested from the information accumulation group.

At this point, the potential applications are categorized in further detail. The following lists are examples of how a set of general categories might be expanded.

- (1) Marine Market
 - a. Cabin lights, running lights and floodlights
 - b. Recreational equipment
 - c. Warning devices (bouys, etc.)
 - d. General accessories

- e. Communication equipment
- f. Navigational aids
- g. Docking and mooring equipment
- h. Battery chargers
- i. Emergency equipment
- j. Cooking, food preparation and storage appliances

(2) Security Market

- a. Commercial intrusion detection equipment
- b. Residential intrusion alarm equipment
- c. Remote area and perimeter lighting
- d. Emergency lighting
- e. Camera surveillance equipment
- f. Fire detection equipment
- g. Gas accumulation detection equipment
- h. Vehicle detection equipment
- i. Railroad and truck tracing equipment
- j. Balloon surveillance systems

(3) Communications Market

- a. Remote telephone repeater stations
- b. Remote television repeater stations
- c. Emergency telephone communications
- d. Ground rescue communications systems
- e. Air rescue communication systems
- f. Law enforcement and fire emergency communication remote command center equipment

(4) Large Scale Power Generation

- a. Portable equipment
- b. Standby and emergency lighting equipment
- c. Intermediate size generators for small municipalities
- d. Combination fuel cell, thermoelectric generators and solar cell systems

(5) Consumer Product Market

- a. Garden care equipment
- b. Automobile accessories
- c. Residential weather stations
- d. Toys and games
- e. Outdoor food preparation
- f. Novelty items
- g. Hobby equipment
- h. Outdoor appliances

- (6) Auxiliary Power and Peak Overload Equipment Market
 - a. Remote power supplies
 - b. Failure detection equipment
 - c. Fire protection equipment
 - d. Emergency cooling and heating power supplies

- (7) Safety Equipment Market
 - a. Road barriers and flasher equipment
 - b. Emergency beacons
 - c. Pollution warning equipment
 - d. Standby road and rail traffic control systems
 - e. Standby air traffic control systems
 - f. Law enforcement and fire department emergency systems

- (8) Food Processing Industry
 - a. Emergency power for batch mixing controls
 - b. On-site preservation processing

- (9) Automotive Industry
 - a. Automatic battery charging system
 - b. Vehicle detection and locator system

- (10) Commercial Transportation Industry
 - a. Railroad standby power supply
 - b. Aircraft rescue beacon
 - c. Truck cargo location system

- (11) Petroleum and Chemical Processing Industry
 - a. Pipeline monitoring equipment (flow rate, etc.)
 - b. Standby batch control power supplies
 - c. Raw material processing equipment
 - d. Power supplies for remote drilling and geological test and analysis equipment

- (12) Forestry and Conservation
 - a. Snow pack monitoring devices
 - b. Wildlife tabulation telemetry equipment
 - c. Smoke detection equipment
 - d. Flood control telemetry
 - e. Standby and remote power supplies
 - f. Camper and visitor control sensors
 - g. Rescue equipment
 - h. Irrigation control

(13) Leisure Time and Recreation Market

- a. Camper cooling and heating equipment
- b. Sports timing and scoreboard equipment
- c. Golf cart battery recharging system
- d. Metal locator power supply system

(14) Construction Industry

- a. Solar roof system - heating and refrigeration system
- b. Total solar home
- c. Survey equipment - laser power supply battery chargers
- d. High-rise elevator emergency power generator systems

The potential systems and concepts are then analyzed from the economic viewpoint after all pertinent information has been accumulated.

1.3.1 Accumulation Of Information

Information is accumulated through a comprehensive literature search which includes books, research papers, periodicals, news releases, government documents, etc. In addition, telephone interviews are set up with key authorities in each marketplace under investigation. These telephone interviews are conducted with a systematic approach and after substantial preparation. Questionnaires are prepared and mailed to individuals who might contribute to the investigation. For example, this could be a sampling of the directors of the 3,110 United States electric light and power utilities, state purchasing agents for emergency road flashers, or anyone in a position to provide information useful in formulating practical system or product concepts.

Additional correspondence requests a specific appointment time, with several alternate time suggested. Once a time has been confirmed, the telephone interview call is placed. The obvious advantage of this technique is that the interviewee has advance knowledge of the subject and can prepare himself. Also, since previous correspondence has occurred, the interviewee is always more congenial than he would be in response to a "cold" call. This interview method has proven to be highly cost effective.

1.3.2 Financial Study

The financial study considers many factors related to the ultimate practical usage of the proposed product or system. The factors considered include:

- (1) The size, stability and growth of the market
- (2) Return on investment
- (3) Estimated annual sales
- (4) New fixed capital payout time
- (5) Time to reach estimated sales volume
- (6) System price acceptance
- (7) Solar cell system cost as compared to volume

Item (7) is a key to the ultimate practical implementation of any proposed system and merits special discussion. A projected price/unit volume relationship will be constructed for each proposed application, based on known engineering and other factors. The data will be based on market research and the many years of production experience of Heliotek accrued during the production of over three million photovoltaic devices. The prices developed will reflect both advanced technology and projected production costs using automated techniques but will not consider the possibility of scientific breakthroughs. As additional data is gathered in later stages, the anticipated project/unit price relationship will be developed. Therefore, the financial feasibility study step is shown as a continuous loop, always being updated and refined.

1.3.3 Field Surveys

1.3.3.1 General

Contact with potential users is conducted during this stage of the development plan. The contacts are basically accomplished through the following methods:

- (1) Individual personal interviews
- (2) Cluster interviews at trade shows, meetings of professional societies, etc.
- (3) Direct mail interviews
- (4) Additional telephone interviews

The objective of the field survey step is to establish the probable acceptance or rejection by the user of the proposed product or system.

During the initial screening processes, opinions of key individuals in the market under study are gathered. As the evaluations proceed and attractive applications are isolated, the surveys are directed more towards the end user.

1.3.3.2 Example of the Interview Method

As an example of the processes involved in information gathering and field survey techniques, a potential application has been selected on a hypothetical basis. The selection is based on a potential application of solar cells for marine use. This application might be grouped in the marine field, together with unattended bouys, etc., and might be discarded during screening. However, the marine market as a group would most likely be retained as a major category.

Artist conceptions of the application are prepared so that the interviewee can establish in his mind the system concept.

Assume that the initial visualization steps have established that the \$3.6 billion boating segment of the leisure time market may have a need for a system designed to maintain the charge on sailboat batteries. Further research has shown that sailboats in the 18 to 36 foot class generally do not have motor generators to furnish charge to the batteries. Marine distributors contacted by telephone and personal interviews have expressed favorable interest. Engineering factors have been considered to the extent that the system appears feasible.

A survey questionnaire is now prepared to determine the end user's level of acceptance. This questionnaire is mailed to a sampling of registered boat owners. A variation of the questionnaire would also be mailed to the 360 domestic manufacturers of boats.

The questionnaire is similar to the personal interview and telephone questionnaire except that a cover letter requests cooperation from the potential respondent. The cover letter explains the purpose of the sample questionnaire and provides a minimum of information so as not to lead the potential respondent into his answers. The letter is designed to solicit the maximum response from statistical viewpoint; that is, maximum responses obtained from the minimum mailing result in the most cost effective approach. As an inducement, the cover letter offers a free gift. This offer substantially increases the number of responses for any mailing. The subject of the offer is generally a publication which has been designed for maximum appeal to the recipient.

The questionnaire is designed to obtain general information. For example, a questionnaire related to marine applications would cover:

- (1) Type of equipment used
- (2) Boat usage
- (3) Respondent's ratings of the advantages of a solar cell system
- (4) Overall acceptance of the respondent to solar cell system concept
- (5) Price acceptability

The number of questions is limited to less than twenty-five, otherwise the potential respondent becomes discouraged and may not complete the questionnaire. There are usually additional questions one would like to ask; however, this limitation has been established empirically during the course of numerous mailings. Since the potential respondent has no prior knowledge of the device in question, and the interviewer is not at hand to furnish any detailed explanations of the device, methods have been devised which lead the respondent into an impartial decision path. For the present program these questions will list the advantages of a solar cell system and ask the respondent to rate these on a point scale. During the rating process, the respondent learns of the advantages of the system indirectly. Information obtained through the series of questions relating to possible advantages is effectively used in later stages of product development, advertising and sales promotion programs, since the advantages rated highest reflect the most desirable feature from the respondent's viewpoint.

Returns from the direct mail interviews generally peak about twelve days after mailing and continue through the fourth week.

1.4 Screening and Evaluation

The screening and evaluation process is directed toward the objective of selecting a minimum of ten (10) potential applications of solar cells to be approved by NASA prior to the conceptual design phase.

A discussion of the criteria for screening and evaluation as well as the tools used in making the evaluation are detailed in Section 3 of this report.

2.0 CATALOGING OF CANDIDATES

2.1 General

A total of sixty-six (66) potential solar cell applications were cataloged during the study program. Listed in Table 2-1 are those applications that show promise within five years. Table 2-2 lists those candidates that have potential in more than five years. Listed in Table 2-3 are those items that did not survive the initial screening process.

At the outset, those markets which have high growth rates and large volumes that would most likely accept new product and system concepts were reviewed. These types of markets can generally support an initial capital investment should one be required.

A number of these markets were grouped and categorized, and several were given priority because of seasonal trade shows, availability of key personnel, and other factors which made data collection more effective.

Guidelines for the identification of specific needs were gathered from the following sources:

- (a) Personal interviews
- (b) Government documents
- (c) Industrial sources
- (d) Literature search of books, research papers, periodicals, news releases

The potential applications were grouped into the following general categories for purposes of cataloging:

- (1) Marine
Oceanographic, marine navigation, and commercial and recreational boating applications

- (2) Transportation
Air and ground transportation, traffic safety and control applications
- (3) Recreational
Applications related to recreational vehicles and facilities
- (4) Medical/Veterinarian
Wildlife and livestock health and research applications
- (5) Security
Applications related to property protection and safety
- (6) Communications
Radio and telephone communication systems of all types
- (7) Meteorological
Applications related to sensors, various kinds of instrumentation, and data acquisition systems
- (8) Instrumentation Control
Power for control and/or monitoring of various kinds of machinery and instruments
- (9) Environmental Protection
Applications related to sensors and other instrumentation for environmental protection and control
- (10) Auxiliary Power
Applications where solar power could augment existing power source or be used in emergencies
- (11) Construction
Applications related to construction of buildings

- (12) Advertising
Power for various types of advertising displays
- (13) Education
Use of solar cells in science curricula and educational equipment
- (14) General
Standard solar power modules for various applications
- (15) Agriculture
Applications related to irrigation, pest control, etc.
- (16) Food Processing
Solar power for cooking devices

There are, obviously, some potential applications that could be included in more than one of these categories, and some categories that could be eliminated by recategorizing some of the applications. However, these categories fairly represent the broad spectrum of potential solar cell applications.

2.2 Approach

The following paragraphs typify the approach used in the cataloging task and the results of this work.

2.2.1 Solutions to Urban Problems

Analysis of ecological, cultural and social factors led to identification of problems faced by urban areas as a potential candidate. Initial research revealed that the solution to urban problems was approached, in a broad sense, by a previous NASA study in conjunction with the International City Management Association (ICMA) in the latter part of 1970, for the purpose of applying NASA technology to urban problems. Selected ICMA member cities were invited to

participate. Of the 100 cities asked, 79, representing a population of almost 20 million, joined.

Nearly 500 problem statements, submitted by January 1971, were independently reviewed. A coordinating group compounded this set of problems into 45 generic, high-impact urban technology requirements. Major problem areas included communications, law enforcement, fire safety, transportation system control, public works and utilities, health, sewage disposal, solid waste management, and water pollution control. The problem statements for 15 top priority problems were rewritten and these were reviewed and modified by three regional groups of city representatives to create regional problem priorities. The coordinating group reconvened in April 1971 to agree on a set of six target problems on which to begin work immediately. The 15 problems in order of priority are:

1. Firemen's breathing apparatus
2. Short-range communications equipment for firemen and police
3. Pavement striping
4. Firemen's protective clothing
5. Underground pipe and conduit locator
6. Automatic fire hose flow regulator
7. Command/control systems
8. Protective body armor
9. Disposal of toxic and flammable waste
10. Electrical fault detection
11. Electronic traffic counter
12. New fire hose and hose couplings
13. Patient monitoring equipment, emergency
14. High voltage power transmission
15. Patient monitoring equipment, non-emergency

Although many of the targeted problems obviously could not make effective use of solar cell technology; items 2, 7, 10 and 11 represented candidates worth considering for further evaluation.

A number of other government industry sources for data on urban problems was also studied.

2.2.2 Marine Candidates

In the marine field, a number of types of remote sensors could be powered by solar energy. The initial concept was to provide a suitable oceanographic system composed of a standard solar array, battery and transmitter which could accept a wide variety of sensors. Applications for such instruments could include:

- (a) Determination of the dynamics of ocean currents
- (b) Wave analysis
- (c) Pollution monitoring
- (d) New and more accurate navigational aids
- (e) Deep ocean survey markers
- (f) Sensors used in biological research of fish habitats
- (g) Weather prediction
- (h) Seismic, gravity and magnetic detection equipment
- (i) Search and rescue communication equipment
- (j) Offshore traffic control
- (k) Tsunami warning devices
- (l) Self-propelled semisubmersible craft
- (m) Aquaculture research stations

All of these devices were studied to determine their practicability for use with a standard solar energy supply.

In addition, solar arrays for use with marker buoys and for battery charging in the marine recreational boating industry were cataloged. Updated information about the boating industry was accumulated and evaluated since manufacturers, harbor masters and owners of commercial boats were more accessible during the winter months, at the time the NASA program was initiated.

2.2.3 Meteorological and Environmental Devices

Previous studies involved preliminary research into the use of solar power supplies for weather monitoring, atmospheric pollution monitoring, and ocean platform equipment. This research included attendance at the Second Symposium on Meteorological Observations and Instrumentation held in San Diego, California on March 27 through 30, 1972.

The general conclusions drawn from this research were:

- (1) The U.S. has apparently been lagging in weather instrumentation purchases, the largest sales being made to foreign markets.
- (2) Very little effort has been expended thus far in the application of solar power to meteorological and environmental instrumentation.
- (3) Sales of meteorological equipment for the 1970-72 period lagged behind 1965-69 levels, but are now on the upswing again.
- (4) The trend is toward automated equipment and a systems approach, with a consequent demand for more low-maintenance, unattended instrumentation systems.

These general conclusions pointed up the probability of a market for solar power supplies both in the U.S. and abroad in the coming years.

Additional research under the scope of this contract reinforced our original conclusions. Data gathered indicates that this market will grow at an even faster rate than originally indicated, for the following reasons.

The size of commercial aircraft, the numbers of people traveling in them, the speed of air travel and the distances covered are all increasing and will continue to increase for some time to come. From the standpoints of both

safety and efficiency of operations, it is apparent that meteorological forecasting must be improved and expanded. This means more and better instrumentation, including greater numbers of remote, automated equipment, which represents a potential application for solar power.

Secondly, the problems of environmental pollution can be expected to become more severe before significant progress is made in their alleviation. Strong legislation is being enacted, and more will come, calling for ever stricter controls and monitoring. Thus, the market for this type of instrumentation can also be expected to grow exponentially, with a corresponding increase in the demand for solar power--both as a reliable means of powering remote, unattended equipment and as virtually the only pollution-free source of electrical energy available today.

Finally, a long-range market potential for solar power exists in the growing demand for, and extensive research into, automatic climate and weather control systems.

2.3 Some General Observations

During the cataloging process, as field research data was tabulated and analyzed, some general observations and conclusions were drawn.

Interest in solar cell applications was higher in the southeast and southwest sections of the country than in the northwest and northeast. In the northern areas, the feasibility of solar cell powered equipment was questioned by respondents because of overcast weather conditions, snow, forest and mountain shading, etc. However, a high percentage of respondents are not familiar with solar cells and arrays and believe that equipment so powered will operate only when in direct view of the sun. An understanding of the concept of energy storage during non-daylight hours is therefore essential in gaining favorable acceptance for solar powered systems.

A second generalization that developed was the premise of attempting to identify applications for solar cells in obvious "remote" areas. Although even modest applications are a start, an appreciable impact in solar cell use must be realized if the manufacturing cost is to be substantially reduced. This implies that domestic urban uses, not rural remote applications, deserve the highest study priority.

Respondents were also concerned with the ruggedness of a solar array and, most important, the ability of the units to withstand vandalism. This problem was graphically demonstrated while interviewing rangers in the Angeles National Forest near Los Angeles. Rangers found it necessary to padlock some fire reporting call boxes because of the excessive amount of vandalism in the area. Also, microwave repeater stations and other outside equipment have often become targets for hand guns and high powered rifles.

Several suggestions have been offered to minimize vandalism and other hazards.

- (a) In order not to attract attention to the equipment, do not use bright colors. In some cases, consider the use of camouflage.
- (b) Mount the equipment on a pole or as high off the ground as possible.
- (c) In general, do not post "do not tamper" or "keep off" signs except on building type installations which have alarms installed. These signs are invitations to vandals. "Scientific Ecological Experiment in Progress" signs have found to be generally more effective than warning signs.
- (d) Depending on the location, both domesticated and wild animals can cause damage to and be injured by outside equipment. The equipment should be placed off known animal paths wherever possible.

- (e) Secure the equipment with as heavy a mount as feasible. Permanently weld the mount to the equipment in order to make carrying of the unit more difficult.
- (f) Permanently engrave an identifying serial number in at least two locations on the equipment. One number should be visible, the second number should be concealed.
- (g) In applications where there is constant activity such as maintenance, or in marine applications, the solar arrays should be protected against being stepped on, stood upon, and against small hand tools being dropped on the array.

One factor apparent in the replies to all of the questionnaire mailings and in personal interviews is that the majority of people, even in the technical professions, have very little knowledge of solar cells. The prevalent opinion remains that a solar array will produce no power output unless it is exposed to direct sunlight. This fortifies the belief that a general program of publicity should be considered in order to acquaint potential users with the general characteristics of solar cells, how they work, and the fact that they will generate electrical power when exposed to any kind of light, and that batteries can be used as storage devices during non-daylight hours.

2.4 Description of Survey Areas

The following subsections outline some of the activities during the cataloging phase, considerations influencing the initial evaluation process, and preliminary conclusions drawn concerning the potential profitability and other benefits of the various solar cell applications. These discussions are a representative cross-section rather than a complete documentation of this work.

2.4.1 Marine Equipment Market

During the program, a representative attended an International Boat Show to gather information on the interest and acceptance of solar panels for use on power boats

and sailboats, and for emergency and rescue equipment. Interviews at the show were divided into six categories:

- (1) Boat manufacturers
- (2) Boat sales organizations and representatives
- (3) Emergency and rescue equipment manufacturers
- (4) Emergency and rescue equipment sales organizations
- (5) Boat owners
- (6) Potential boat buyers

The following general conclusions were drawn from this survey:

- (a) There is a high level of interest among boat owners and manufacturers in a solar power supply to maintain the charge on the boat's battery.
- (b) Power boat owners and manufacturers are particularly interested in the use of solar power when boats are anchored offshore.
- (c) Sailboat owners and manufacturers place emphasis on maintaining battery charge without running the auxiliary engine and in recharging the battery in less than one week.
- (d) Emergency and rescue equipment manufacturers showed a high level of interest for a number of different applications of solar panels, with emphasis on ruggedized construction.

A regional boat show in Long Beach, California was attended. As well, direct mail surveys among boat manufacturers, dealers, and owners were conducted. The above conclusions were further validated as a result of this research.

The use of solar power for marine buoys was evaluated through contacts with the U.S. government and private firms, both domestic and foreign. Many of the standard marine buoys are powered by propane gas and incorporate lights that use propane gas directly. However, other types are equipped with electrical lights

and nonrechargeable batteries. There is considerable room for improvement in this field. Industry sources reveal that a standard buoy must provide a visible indication over a range of four nautical miles when visibility is fair. It would be desirable to provide sufficient light output to make the buoy visible at the same range under conditions of poor visibility. Present requirements specify an approximate battery power output of 40 to 60 watts when using an incandescent lamp.

2.4.2 Temperature Monitoring of Livestock

The application of solar cells to power a small transmitter carried by animals for wildlife tracking studies was an interesting application. This is a candidate for the NASA study which might use a very small group of solar cells to power a simple transmitter device attached to a low-cost temperature sensor. The sensor is implanted by a simple process in newly born calves.

The temperature of the animals is extremely important, particularly in the feed lot industry when cattle are shipped from ranches to the feed lot. They are medicated immediately if their temperature is over 103°F. When in feed lots, they are more susceptible to disease, particularly respiratory illnesses.

The concept would involve the transmission of a low-powered RF CW signal when the temperature reaches a predetermined point. A simple hand-held detector would be used to isolate the sick animal and would thereby provide advance warning to reduce the spread of the infection to other animals.

2.4.3 Traffic Safety Devices

Under the general category of Transportation, a number of potential candidates involving traffic safety devices were screened and evaluated. These included various types of warning lights, trouble lights and kits, utility lights, strobe lights, dome lights, sequencing lights, high-intensity lamps and rechargeable lamp systems for remote areas. Among these, the solar powered safety barrier flasher appeared the most promising. Background information on this subject had been gathered previously; however, since this is a high interest application, additional detailed study was devoted to this candidate.

On December 29, 1970, President Nixon signed the Williams-Steiger Occupational Safety and Health Act of 1970 (Public Law 91-396) which established a national commitment towards improved safety. Subsequently, a Compliance Operations Manual was published in January of 1972 (OSHA-2006) by the Occupational Safety and Health Administration. Specific health and safety guidelines are set forth in the manual, accompanied by severe penalties to construction employers for violations. Adequate warning lights are an important consideration of the manual, and the new specifications require increased use, more reliable and brighter lights. Options open to the manufacturers of barrier flashers involve adding additional battery capability or changing existing battery types more frequently.

Although a flasher unit which is recharged by solar energy certainly would fill an important need, concentration was placed on how the construction industry might accept higher cost devices in view of the more stringent new and future standards. A survey of all barrier flasher manufacturers and a cross section of users was conducted to determine the most responsive design concepts which fulfill the newly established requirements.

A new publication, "Manual on Uniform Traffic Control Devices," has been published by the U.S. Department of Transportation - Federal Highway Administration. This manual summarizes state and industry specifications.

2.4.4 Environmental Protection Applications

Extensive research was conducted to identify potential applications for solar cells in the field of environmental protection and monitoring.

As an example, all principal air pollution researchers under private, state, federal and foreign sponsors have been contacted by direct mail and telephone conferences. This list, containing 1,383 research programs, was compiled by the U.S. Department of Health, Education and Welfare.

Manufacturer's catalog data sheets were obtained in order to determine typical power requirements for existing equipments in this and other fields. Extensive study was devoted during this phase to a specialized application within the Environmental Protection Category in the form of a noise pollution monitoring system that could be solar powered. This application is based on the increased use of off-road recreation vehicles (ORRVs) and the resultant impact on the environment.

2.4.5 Water Supply Distribution Command/Control System

An interesting new application developed during this study is a solar powered monitor and telemetry system that would be used by utilities for water supply optimization programs. Optimization of the water supply with respect to economy is achieved through a process computer which takes into account the currently available supply of water from several reservoir sources.

Local authorities as well as foreign utility officials contacted expressed a definite interest in the use of solar power for these monitoring devices.

A second area of considerable interest involves the protection and security of the water systems. As in any city, there exists the constant danger that irresponsible individuals may gain access to reservoirs or the pumping systems and contaminate these with dangerous chemicals. Public water systems are therefore extremely interested in perimeter protection systems which could be integrated with a warning system. This perimeter protection system would become feasible if solar power supplies could be used to operate various electronic devices. (See discussion of perimeter protection system in Section 4.0 of this Volume.)

2.4.6 Educational TV System

A solar power supply for TV receivers to be used in an educational experiment whereby educational programs would be beamed to remote areas via satellite was discussed briefly with NASA personnel early in the program. Additional research during the screening and evaluation task verified that this was a strong potential candidate.

This program, known as the Health/Education Technology (HET) Experiment, is being developed by the Telecommunications Office of the Department of Health, Education and Welfare. The initial phase of the program is to be conducted for and in cooperation with the Federation of Rocky Mountain States. The NASA ATS-F satellite, to be launched in April, 1974, will be used to beam experimental educational TV programs to remote areas in the western states. Detailed requirements for the TV receivers to be used in the experiment have not been fully defined. However, it was determined that battery powered standard commercial TV sets will be used, along with an auxiliary converter unit for reception on the special frequency to be assigned. Duration of this initial phase is scheduled for one year, beginning in September 1974, concurrent with the school year. Upon completion of the experiment in the Rocky Mountain region, the satellite will be moved to a position over the Indian Ocean and the experiment will be continued with educational programs beamed to India and possibly other Asiatic countries.

Relative to the probable power requirements for the battery operated TV receivers to be used in this program, some preliminary calculations based on available data were made. The average black-and-white TV set requires 237 watts of power; the average color set 332 watts. The majority of sets presently in use utilize vacuum tubes rather than transistors. Since the educational TV sets for the HET program are to be battery operated, a solid-state set would be preferable since they require considerably less power, 50 watts or less. However, the cost of solid-state sets could be prohibitive. Officials at HET indicated that 10 to 15 watts were required for the frequency down-converter unit. Although the present market for a solar power supply in this application is quite small, the potential future market could be very large, assuming that the experimental program proves successful.

2.4.7 Solar Powered Refrigeration Unit

This application was also discussed briefly with NASA personnel early in the program and was researched further during the screening and evaluation phase.

In discussions with U.S. Department of Agriculture personnel as well as dairy industry scientists, it was learned that there is a very definite need for refrigeration units capable of storing milk, and possibly other foods, in the underdeveloped countries. The Department of Agriculture for some years has been supplying surplus milk purchased by the Government under the price support program to charitable institutions for distribution, usually in powder form. Powdered milk shipped overseas is usually reconstituted, pasteurized and bottled for distribution to needy families. Occasionally it is combined with local dairy products in what is known as a "toning" operation. Reconstituted powdered milk, assuming that it has not been exposed to contamination and that it has been pasteurized, can be stored under the same conditions and for the same length of time as ordinary whole milk. At the present time, however, due to lack of suitable refrigeration facilities at the consumer level in underdeveloped countries, the milk is distributed in small quantities intended for immediate consumption.

Pasteurized whole milk which meets Government standards for bacteria count can be stored at 40°F for 14 to 21 days in the carton. Each degree of increased temperature shortens the shelf life by one to two days. Thus, at 45 degrees, the milk will remain safe for only 5 to 10 days. Most dairies process and store their milk at a temperature slightly lower than 40 degrees in order to provide a safety factor. For the same reason, their goal is to process the milk so as to achieve a shelf life of 10 days at 50 degrees.

From the foregoing, it is apparent that a refrigeration unit for the purpose of storing milk should be capable of maintaining a fairly constant temperature, preferably at about 40°F, and not more than 50°F as a maximum. The electrical power requirements are of course a function of the cubic volume of space to be refrigerated, and the average temperature differential between the interior of the unit and the outside air. A 12 cubic foot home refrigerator using

conventional compressors consumes an average of about 240 watts 24 hours per day; however, it has been determined that a 2 to 3 cubic foot unit would probably be satisfactory for this application.

Dr. Pallansch, of the U.S. Department of Agriculture, indicated in a telephone interview that if such a unit were available it could be used also for storage of other types of food and this would considerably broaden its marketability.

2.4.8 Satellite Telephone Relay Systems

Solar power for satellite telephone relay systems was one application under the general Communications category that was studied in depth during the program. As an example of the size of this potential market, Brazil, the largest nation in South America is considering expenditure of roughly \$100 million to acquire a domestic satellite communications system that would link its cities with remote areas isolated by jungles and mountains.

Proposals from several companies are currently under study by a special commission of the Brazilian government. President Emilio Garrastazu Medici will make a selection between Hughes Aircraft Company, El Segundo; the TRW Systems Group, Redondo Beach, a unit of TRW, Inc., Cleveland; the Fairchild Space and Electronics Systems unit of Fairchild Industries, both located in Germantown, Maryland; General Electric Company, New York; and a Franco-German group headed by the French firm, Aerospatiale.

The project would be purely a domestic system, beamed to cover Brazil alone, a country with about five telephones for every 100 persons today, compared to approximately 75 for every 100 residents of the United States.

The system would bring effective communications to remote regions which either cannot now be reached by ground systems or which at present can be serviced only unreliably and uneconomically.

It would relieve an increasing burden on Brazil's telephone system that has been undergoing modernization only in the last five years or so after more than three

decades of stagnation. Should Brazil move ahead on the proposals, they would become the third country in the world to have a nationwide domestic satellite communications system.

Canada was the first with Anik 1, launched in orbit in November 1972, the first of three ordered by Telesat Canada from the Hughes Aircraft Company, to link 37 ground stations. Another Anik will be added to the Canadian system soon, while a third will be a backup system.

The U.S. also will be served by domestic systems, including Western Union International, which will have three orbiters aloft (the first in the spring of 1974), with one on earth-standby. American Satellite (AMSAT) also plans to use satellites for private line services, such as the stock market.

The satellite to be used in Brazil is the Hughes HS-333 launched by NASA. Education is also an important part of the system application and solar power supplies could be a natural application just as in the HET experiment. After school hours, it was pointed out, the receiving antennas in isolated villages could be used for adult education, news, public health service, agricultural information, weather data--or simply for entertainment.

2.4.9 Desalination of Salt Water

A study of the use of solar power in the desalination of salt water was conducted, primarily on a small scale basis for islands and remote locations, since fresh water is becoming an increasingly more valuable natural resource. The world's largest experimental desalting unit is producing some 2.5 million gallons of fresh water per day in San Diego, California. This test facility is designed to provide data for desalting plants in the future. Brackish and salt water are being converted to fresh water in many parts of the world. In humid or moderately humid areas, the cost of such water is higher than that of surface and ground water. Several lines of research are being pursued to reduce the cost and to provide greater flexibility in the use of brackish and salt water. Efforts of the Federal Government, States and universities are being actively continued.

Desalination also can be used to purify polluted as well as brackish water. However, the consequences of discharging the effluent of desalination into coastal waters must be studied carefully by the Coastal Zone Authorities before large desalination plants are installed.

2.5 List of Candidate Applications

2.5.1. Fruition Within 5 Years

<u>No.</u>	<u>Application Code</u>	<u>General Field</u>	<u>Description of Application</u>
(1)	1 M	Marine	Power system for ocean data stations
(2)	2 M	Marine	Solar panels to maintain the charge on boat batteries
(3)	3 M	Marine	Navigational aids: beacons, channel marker buoys
(4)	4 M	Marine	Emergency radio-telephones
(5)	1 T	Transportation	Remote sensors used for traffic counting and control
(6)	2 T	Transportation	Barrier flashers, warning lights for traffic control
(7)	3 T	Transportation	Power supply for general aviation air crash rescue beacons
(8)	4 T	Transportation	Power supply for commercial aviation and military rescue beacons
(9)	7 T	Transportation	Power for automatic railroad car identification system
(10)	1 MV	Medical/Veterinarian	Temperature monitoring of livestock
(11)	2 MV	Medical/Veterinarian	Wildlife tracking transmitters powered by solar cells
(12)	3 MV	Refrigeration	Power supply for small refrigeration unit in remote or underdeveloped areas
(13)	1 S	Security	Power supply for remote perimeter protection devices
(14)	2 S	Security	Power supply for CCTV surveillance system
(15)	3 S	Security	Solar cell power for wireless intrusion sensors
(16)	4 S	Security	Power for alarms that protect remote communication equipment - microwave relay stations, etc.

2.5.1. Fruition Within 5 Years (Cont'd)

<u>No.</u>	<u>Application Code</u>	<u>General Field</u>	<u>Description of Application</u>
(17)	6 S	Security	Monitoring equipment to test water supplies against contaminants, poisons, etc.
(18)	1 C	Communications	Land based emergency radio-telephones for motorist assistance
(19)	2 C	Communications	Fire reporting radio-telephones for wilderness areas
(20)	5 C	Communications	Mobile telephone company vans for temporary systems
(21)	7 C	Communications	Power for TV receivers in remote areas for reception of educational programs via satellite
(22)	8 C	Communications	Power for telephones in remote areas for reception of telephone transmissions via satellite
(23)	1 MI	Meteorological	Power system for seismic detectors
(24)	2 MI	Meteorological	Power system for rainfall and snow level recorders
(25)	3 MI	Meteorological	Power system for total remote data acquisition systems.
(26)	4 MI	Meteorological	Barometric pressure, air temperature, humidity sensors
(27)	5 MI	Meteorological	Airport wind direction and speed sensor and transmitters
(28)	6 MI	Meteorological	Solid state anemometer power supply
(29)	1 IC	Instrumentation Control	Power supply water pumps
(30)	4 IC	Instrumentation Control	Control systems for monitoring stream, lake and reservoir levels
(31)	9 IC	Instrumentation Control	Solar gravity motor and pump system
(32)	1 EP	Environmental Protection	Air pollution sensors and telemetry equipment located in remote areas

2.5.1. Fruition Within 5 Years (Cont'd)

<u>No.</u>	<u>Application Code</u>	<u>General Field</u>	<u>Description of Application</u>
(33)	2 EP	Environmental Protection	Water pollution sensors and telemetry equipment
(34)	3 EP	Environmental Protection	Emission monitoring instruments for smokestacks
(35)	4 EP	Environmental Protection	Sensors for the detection of air radioactivity
(36)	6 EP	Environmental Protection	Power supplies for instrumentation used to monitor noise pollution
(37)	2 AP	Auxiliary Power	Power supply for oil drilling ocean platforms and barges
(38)	1 CI	Construction Industry	Power supply for portable power tools
(39)	1 A	Advertising	Power supply for battery recharging systems for outdoor billboards
(40)	2 A	Advertising	Power supply for point of purchase temporary displays
(41)	1 E	Education	Solar energy scientific experimentation kits for students
(42)	1 G	General	Standard medium power module fixed installation
(43)	2 G	General	Standard medium power module - transportable
(44)	3 G	General	Standard low power module - fixed installation
(45)	4 G	General	Multipurpose low power module - portable (manpack)
(46)	5 G	General	Standard medium power module - sun tracking type
(47)	6 G	General	Standard low power module - portable - forestry communication system
(48)	1 AG	Agriculture	Supply for automatically dispensing insecticides
(49)	2 AG	Agriculture	Combined solar and wind power system for electric water pumps in remote areas
(50)	1 FP	Food Processing	Cooking devices utilizing both thermal and direct energy conversion

2.5.2. Fruition Beyond 5 Years

<u>No.</u>	<u>Application Code</u>	<u>General Field</u>	<u>Description of Application</u>
(1)	5 T	Transportation	Power system for remote aircraft landing fields
(2)	6 T	Transportation	Power for obstruction monitoring devices for railroad tracks
(3)	1 R	Recreational	Battery charging system for campers, motor homes
(4)	2 R	Recreational	Small solar arrays for minimal power at remote cabins and campsites
(5)	3 R	Recreational	Recharging system for nighttime illumination of ski areas
(6)	5 S	Security	Power supply for remote access controls and guard stations
(7)	3 C	Communications	Power supply for unattended radio base station repeating installations
(8)	4 C	Communications	System power for isolated fire lookout towers
(9)	6 C	Communications	Lifeguard tower communications system
(10)	7 MI	Meteorological	Ground-to-aircraft wind speed direction transmitter
(11)	2 IC	Instrumentation Control	Command/control system for water supply distribution systems
(12)	5 IC	Instrumentation Control	Recycling of sanitary facilities in recreation areas
(13)	6 IC	Instrumentation Control	Desalination of water
(14)	7 IC	Instrumentation Control	Supply to power automated chemical mixing plants
(15)	8 IC	Instrumentation Control	Sewage processors and digestors
(16)	5 EP	Environmental Control	Emission monitoring instruments for automobile

2.5.3. Candidates With Low Chance of Fruition

<u>No.</u>	<u>Application Code</u>	<u>Description of Application</u>
(1)	A	Video screen sensor for TV game shows
(2)	B	Automobile headlight activated road markers
(3)	C	Automobile automatic headlight adjustor (adjusts beam continuously rather than bright/dim)
(4)	D	Utilization of silicon cells in consumer camera equipment
(5)	E	Solar cell powered professional motion picture camera
(6)	F	Solar cell powered video camera and recorder system (portable)
(7)	G	Solar cell combination thermo-direct conversion swimming pool heating and filtration system
(8)	H	Solar powered outdoor barbecue grill
(9)	I	Solar powered stop and go traffic signal
(10)	J	Solar powered mobile homes

3.0 PRELIMINARY EVALUATION AND SCREENING

3.1 General

As described in the Methodology section, the preliminary evaluation and screening task was directed toward the objective of selecting a minimum of ten (10) potential applications of solar cells to be approved by NASA prior to the conceptual design phase.

Data used as source material for this task included the cataloged candidates from Section 2.0. Information obtained through the literature search and key man telephone interviews, detailed financial studies of solar cell system costs as a function of probable market volume and comparisons with competitive systems, and field surveys in the form of direct mail and personal factors.

Upon completion of the evaluation and screening, a complete set of Application Evaluation Sheets and Product Evaluation Charts for each of the sixty-six (66) cataloged applications was prepared. Based on the results of these evaluations, ten of the most promising short-term applications were selected and recommended for further study in the conceptual design phase. These applications are described briefly in section 4.0 and in detail in section 4.9 of this report.

A general discussion regarding the use of the product evaluation charts and Risk Analysis computer program in the evaluation and screening process follows.

3.1.1. Product Evaluation Charts

The criteria for screening and evaluation are divided into five basic categories:

- (1) Engineering and development factors
- (2) Economic factors
- (3) Production factors
- (4) Marketing factors
- (5) Opinion research factors

In evaluating product and system applications, it is most important to weigh the qualifications of each potential application within some framework. A scale of a quantitative nature has been formulated which is utilized to rank the various detailed factors.

The qualitative scale is relative and therefore does not indicate the absolute magnitude of importance of one factor over another. As a compromise, a series of relative values is used to weigh the factors. The numerical scale is as follows:

(+2)	Very Good
(+1)	Good
(0)	Average
(-1)	Poor
(-2)	Very Poor
(-3)	Insufficient Data

The numerical criteria assignments are continuously updated and refined as the evaluation data becomes increasingly detailed.

The numerical values are assigned for each factor in the five basic categories. If the anticipated results are average (0), no value is added into the column labeled "points". The total points are added for each category then summed together. This then provides the basic criteria for screening various applications. During the course of the evaluation, each basic category is updated and a new point count is computed. Those applications with low overall point counts are discarded in favor of the higher scoring applications.

The Application Evaluation Sheet used in the screening process follows.

APPLICATION EVALUATION SHEET

(1) Description of application _____

(2) Application code _____ (3) General Field _____

(4) Favorable pattern preliminary check list:

	Rating			
	Very Good	Good	Fair	Poor
Potential Sales Volume				
Possible Market Share				
Technical Feasibility				
Competes price-wise with other means				
Suitability with exist- ing sales and distri- bution channels				
Market stability				
Advertising and Promotional Costs				
Return on Investment				
Social Benefits				

(5) Point Tabulation

_____ Engineering X _____ Industry weighting factor = _____
_____ Economic X _____ Industry weighting factor = _____
_____ Marketing X _____ Industry weighting factor = _____
_____ Production X _____ Industry weighting factor = _____
_____ Opinion Research X _____ Industry weighting factor = _____

(6) Total Score _____

(7) Research Check List:

_____ Contact with key buyers complete	_____ Price sensitivity established	_____ Financial analysis complete
_____ Contact with distributors and representatives complete	_____ ROI estimate complete	_____ Opinion research complete
_____ Point tabulation complete	_____ Preliminary marketing plan outlined	
_____ Literature search complete		

(8) Investigator's Comments: _____

(9) Key outside personal source _____

(10) Principal written authority _____

(11) Investigator's name _____

Total score
from (6) above

ENGINEERING AND DEVELOPMENT FACTORS		Points	
		+	-
Technical risks	(-2) Requires technological breakthroughs (-1) Requires considerable technical experience to develop - pushes state of the art (+1) Requires limited technical knowledge (+2) Feasible with existing technology		
Life expectancy	(-2) Probably 1 to 3 years (-1) Probably 3 to 5 years (+1) Probably 5 to 10 years (+2) Probably more than 10 years		
System or product competition	(-2) Several directly competitive (-1) Several competitive to some extent (+1) One or two somewhat competitive (+2) No competitive product		
Performance	(-2) Equal to competitive systems (-1) Better efficiency at cost of competitive systems (+1) Better efficiency at lower cost (+2) Much greater efficiency at lower cost		

ENGINEERING AND DEVELOPMENT FACTORS (Continued)		Points	
		+	-
Social factors, ecological and cultural advantages	(-2) No noticeable advantages (-1) Advantages at a substantial cost (+1) Advantages at a modest cost (+2) Great improvement at no cost increase		
Form, size esthetics factors	(-2) Ugly and unsightly - difficult to install (-1) Physical problems in installation (+1) Minor installation problems (+2) Easy to install - blends into environment		
Government or Industrial Mandatory Standards and Regulations	(-2) Standards constantly being changed (-1) Standards changed occasionally - not predictable (+1) Standards occasionally changed but with substantial advance notice (+2) Mandatory standards either do not exist or are seldom if ever changed		

PRODUCTION FACTORS		Points	
		+	-
Required size of manufacturer	(-2) Any manufacturer (-1) Most companies could compete (+1) Average or larger sized companies (+2) Only a very large company		
Raw materials	(-2) Limited supply (-1) Limited availability inside company (+1) Readily available outside company (+2) Readily available inside company		
Production equipment	(-2) New plant required (-1) Mostly new equipment (+1) Some new equipment (+2) Present idle plant usable		
Environmental protection equipment	(-2) New plant required (-1) Mostly new equipment (+1) Some new equipment (+2) No new equipment required		

PRODUCTION FACTORS (Continued)		Points	
		+	-
Process familiarity	(-2) New process - no other applications (-1) Partly new - few other uses (+1) Familiar process - some other uses (+2) Routine process - promises other uses		
Labor availability	(-2) Limited availability - requires aggressive recruiting (-1) Limited availability - requires some recruiting (+1) Readily available outside company (+2) Readily available inside company		
Key man availability	(-2) Requires aggressive recruiting (-1) Available outside company (+1) Available inside company (+2) Does not require one		

MARKETING FACTORS		Points	
		+	-
Similarity to present product or systems of manufacturer	(-2) Entirely new type (-1) Somewhat different (+1) Only slightly different (+2) Fit perfectly		
Number of potential customers	(-2) 10 to 100 (-1) More than 100, less than 1,000 (+1) Less than 100,000, more than 1,000 (+2) More than 1 million		
Suitability of sales and distribution channels	(-2) Entire new group required (-1) Extensive training required (+1) Some retraining required (+2) No changes necessary		
Market stability	(-2) Volatile - changing prices (-1) Unsteady market (+1) Fairly firm market (+2) Highly stable market		

MARKETING FACTORS (Continued)		Points	
		+	-
Market trend	(-2) Decreasing market (-1) Static, mature market (+1) Growing market (+2) New potential market		
Technical service and maintenance	(-2) Extensive service required (-1) Moderate service requirements (+1) Slight service requirements (+2) Negligible service required		
Cyclical and seasonal demand	(-2) Seasonal and subject to business cycles (-1) Seasonal (+1) Subject to business cycles (+2) High stability		
Promotional requirements	(-2) Extensive advertising and promotion (-1) Appreciable requirements (+1) Moderate requirements (+2) Little promotion required		

OPINION RESEARCH FACTORS		Points	
		+	-
Opinion research questionnaire - question: would you buy?	(-2) Less than 5% responded affirmatively (-1) 5% to 10% responded affirmatively (+1) 10% to 20% responded affirmatively (+2) 20% or more responded affirmatively		
Media test response	(-2) Inconclusive - less than 25% (-1) 25% relative response (+1) 40% relative response (+2) 50% relative response		
Key buyer response	(-2) Less than 25% positive (-1) Greater than 25% positive (+1) Greater than 40% positive (+2) Greater than 50% positive		
Correlation of Tests	(-2) Greater than 30% (-1) Within 30% (+1) Within 15% (+2) Within 10%		

OPINION RESEARCH FACTORS (Continued)		Points	
		+	-
Overall response	(-2) Less than 30% favorable (-1) Over 30% favorable (+1) Over 40% favorable (+2) Over 50% favorable		
Price sensitivity	(-2) 40% lower than projected (-1) 25% lower than projected (+1) Within 10% of projected (+2) 25% greater than projected		

ECONOMIC FACTORS		Points	
		+	-
Return on investment	(-2) Less than 20% (-1) 20% to 25% (+1) 25% to 30% (+2) Greater than 30%		
Estimated annual sales	(-2) Less than \$100,000 (-1) \$100,000 to \$1 million (+1) \$1 to \$5 million (+2) Greater than \$5 million		
Fixed capital payout time	(-2) More than 5 years (-1) 3 to 5 years (+1) 2 to 3 years (+2) Less than 2 years		
Time to reach estimated sales volume	(-2) More than 5 years (-1) 3 to 5 years (+1) 1 to 3 years (+2) Less than 1 year		

ECONOMIC FACTORS (Continued)		Points	
		+	-
Research and development investment payout time	(-2) More than 3 years (-1) 2 to 3 years (+1) 1 to 2 years (+2) Less than 1 year		
Material and labor costs	(-2) Volatile - price fluctuates (-1) Unsteady - may increase (+1) Fairly stable - predictable rate of income (+2) Highly stable		
Selling price analysis	(-2) Higher price - equipment quality (-1) Competitive, or higher price and quality average (+1) Competitive price but quality average (+2) Both price and quality advantage		

3.1.2. Risk Analysis Program

The Risk Analysis computer program calculates return on investment (ROI) and uses simulation techniques to evaluate and screen candidate applications for solar cell powered systems. Although these analyses cannot predict an outcome exactly, they do offer a rational procedure that can be used to select the most promising candidates. The simulation process, in this case a Monte Carlo method, allows repeated analyses of the complex interactions among the variables which affect the success of a new product venture. In the present case, the original list of variable factors which affect the basic ROI equation has been slightly modified to fit the computer matrix.

The basic ROI equation as used in the solar cell powered product model is:

$$\text{ROI (\%)} = \frac{(\text{Total Sales}) - (\text{Cost of Sales})}{\text{Total Investment}} \times 100$$

Further expanded, this becomes:

$$\text{ROI (\%)} = \frac{(M \times P \times S) - (M \times C \times S) + F}{I \times T} \times 100$$

where

- M = total market size in units
- P = manufacturer's selling price in dollars
- S = share of market expressed as decimal fraction
- C = unit production cost in dollars
- F = fixed additional costs
- I = total investment
- T = coefficient of time dependent factors

During initial screening, the factors comprising the ROI equation are varied and sensitivity plots are produced, showing the effect of one variable on another. Samples of some early plots are shown in Figures 3.1 through 3.8. The first graph shows ROI (the ordinate values should be divided by 10 to obtain yearly ROI) versus investment, with several factors interwoven. The factor T represents $(M \times P \times S) - (M \times C \times S)$ in the ROI equation.

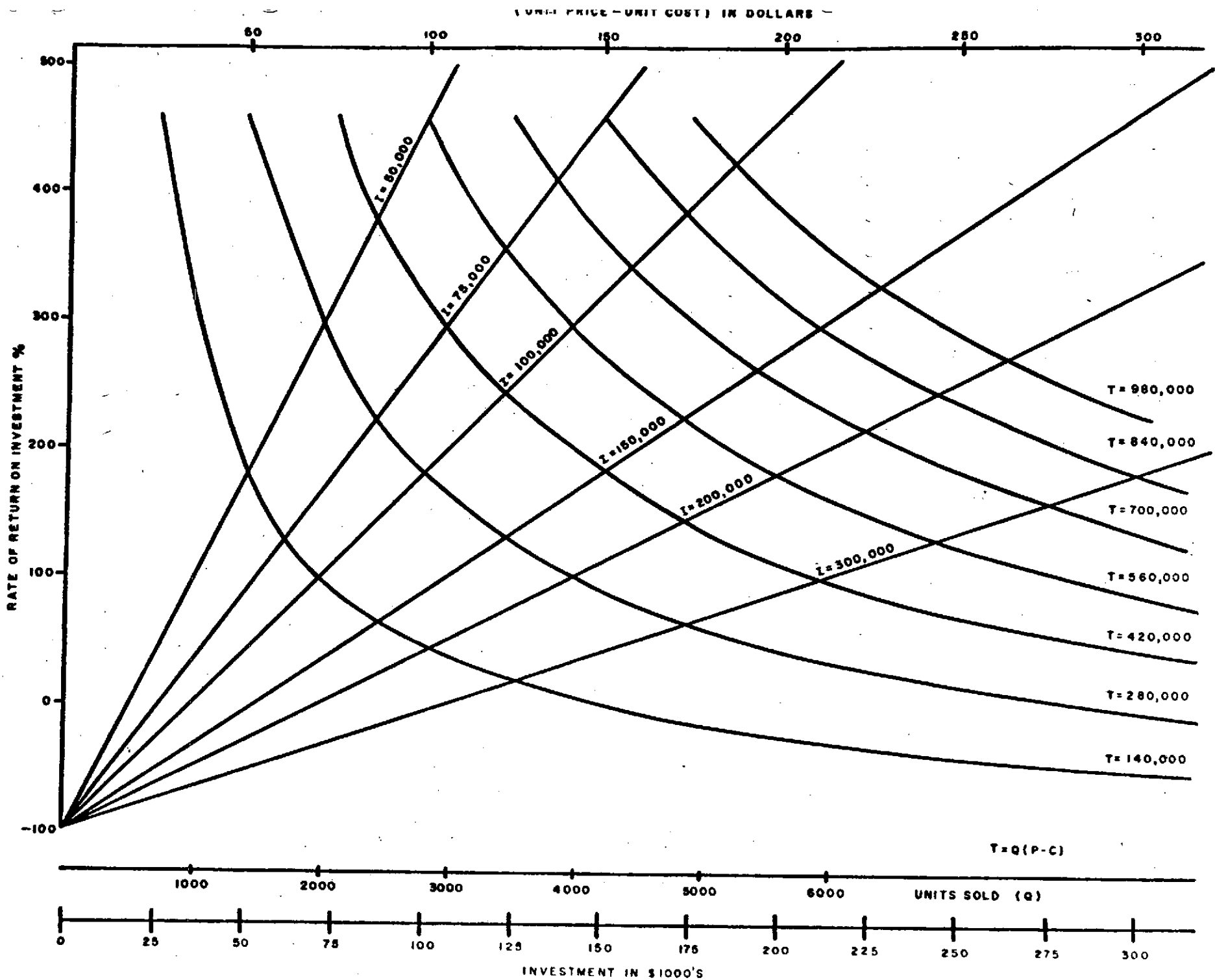
During the latter, more detailed analyses, all evaluation factors are introduced into the ROI equation. These factors, as previously discussed, have been slightly modified and are grouped into five categories as shown in Table 3-1.

Table 3-1 ROI Evaluation Factors

Engineering and New Development Factors (K1)	<ol style="list-style-type: none"> 1) Technical risks 2) Performance 3) System or product competition 4) Performance 5) Life expectancy 6) Form, size and esthetics 7) Social factors
Production Factors (K2)	<ol style="list-style-type: none"> 1) Equipment 2) Process familiarity 3) Raw material availability 4) Labor availability 5) Key man availability 6) Size of manufacturer 7) Environmental requirements-production
Marketing Factors (K3)	<ol style="list-style-type: none"> 1) Similarity to present products 2) Number of potential customers 3) Sales and distribution channels 4) Market stability 5) Market trends 6) Technical service and maintenance 7) Cyclical and seasonal demands 8) Promotional requirements
Economic Factors (K4)	<ol style="list-style-type: none"> 1) Time to reach estimated sales volume (T) 2) Selling price analysis 3) Plant location 4) Material and labor costs (T)
Opinion Research Factors (K5)	<ol style="list-style-type: none"> 1) Questionnaire response-direct mail 2) Media test response 3) Key buyer response 4) Personal/telephone response 5) Overall response 6) Correlation of tests

Each of the five categories is weighted in the computer model, and each of the items within a given category is weighted in relative importance to the others within that category. Different weighting factors are used for different analyses, depending upon the type of product or market under investigation.

Figure 3-1
Return on Investment vs. Investment
3-17



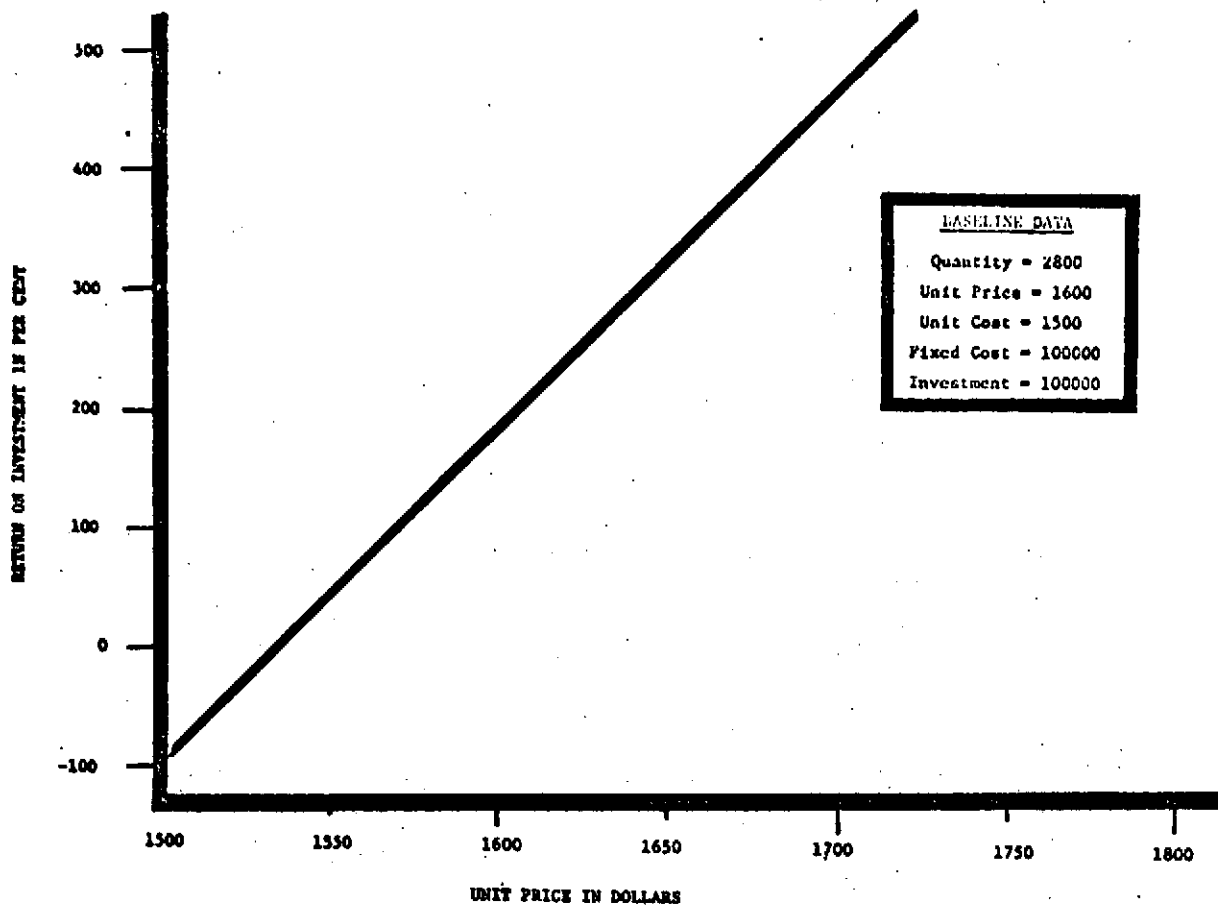


Figure 3-2 Return on Investment vs. Unit Price

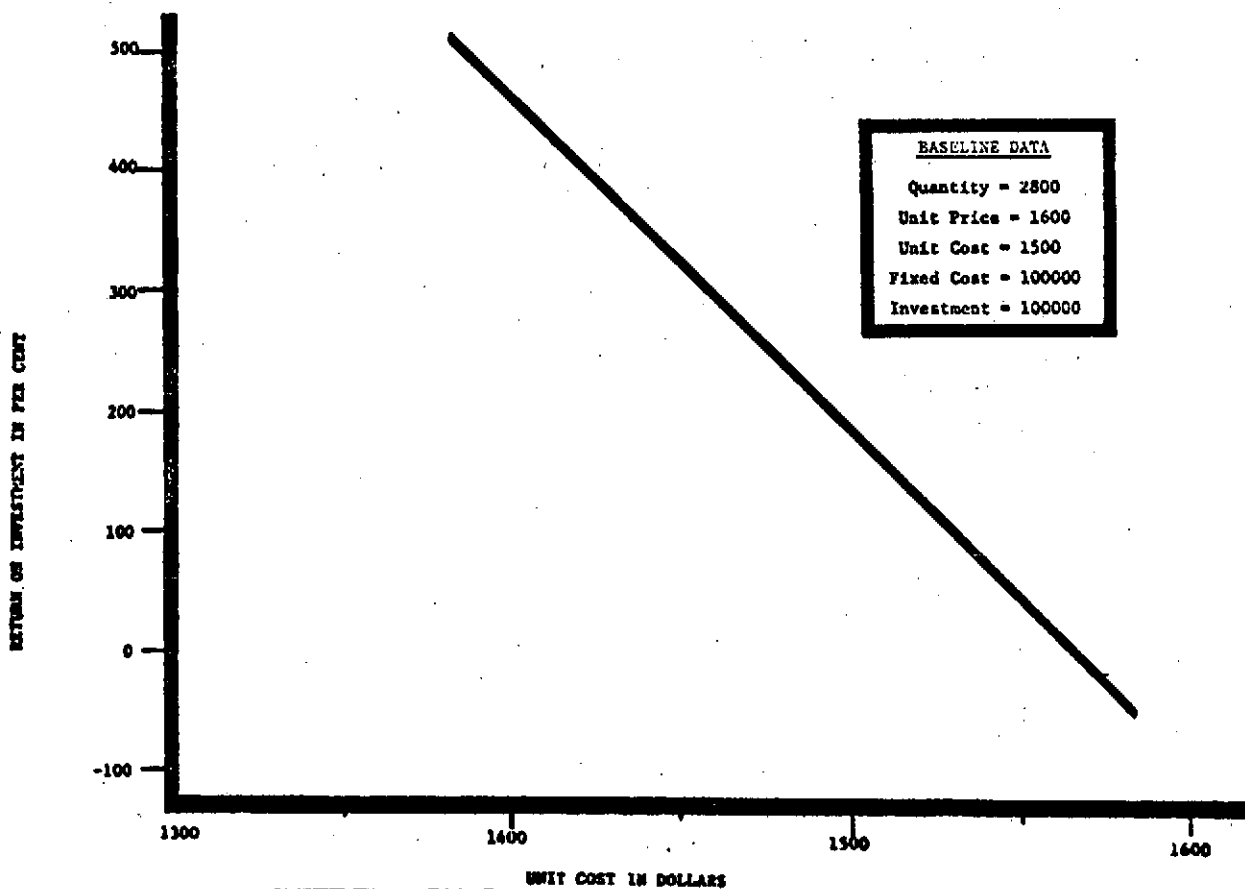


Figure 3-3 Return on Investment vs. Unit Cost

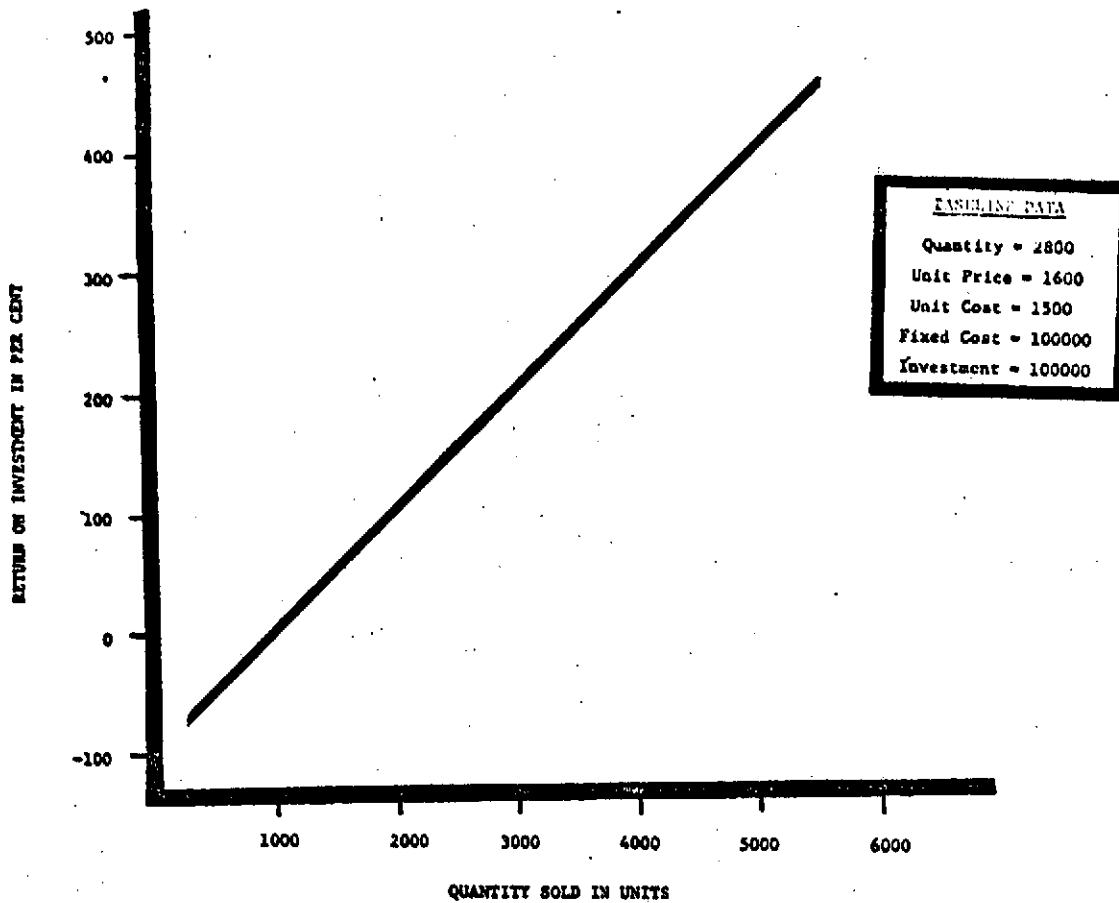


Figure 3-4 Return on Investment vs. Quantity Sold

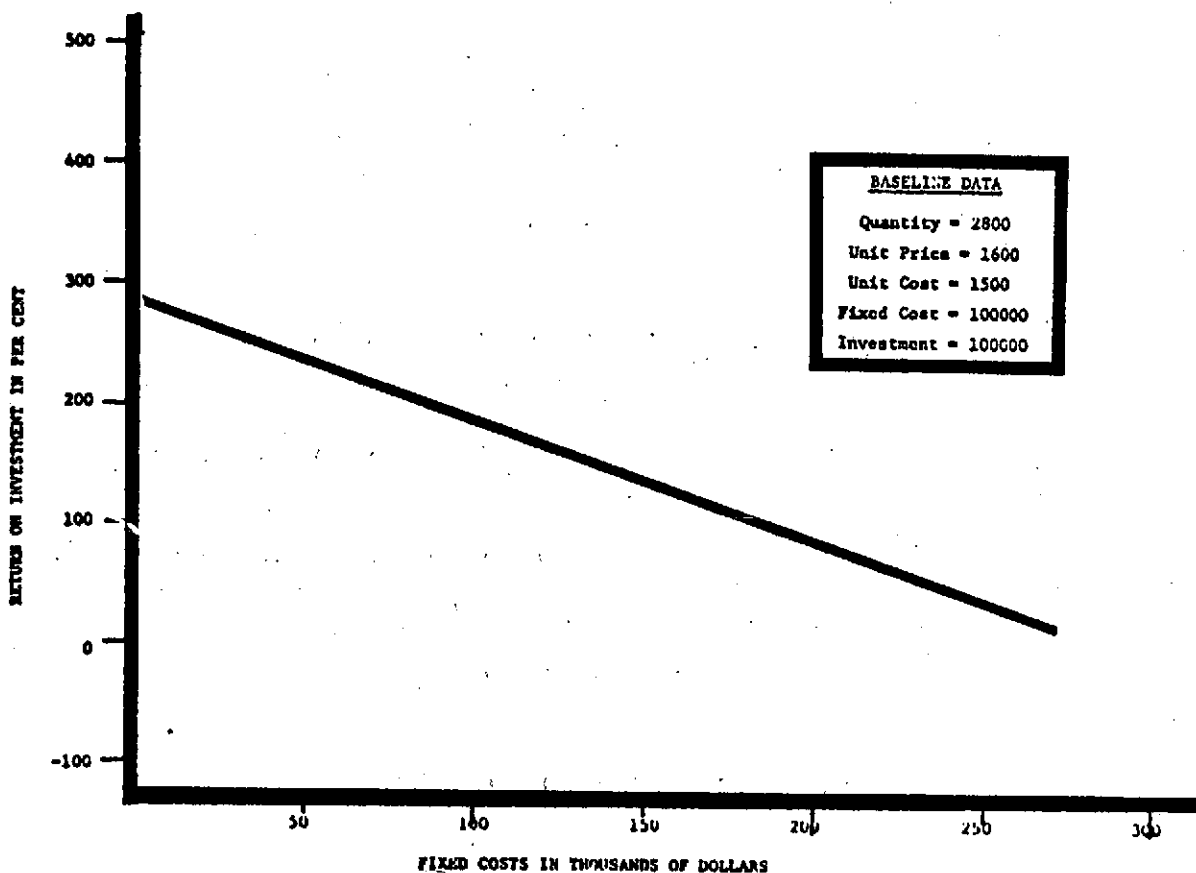


Figure 3-5 Return on Investment vs. Fixed Costs

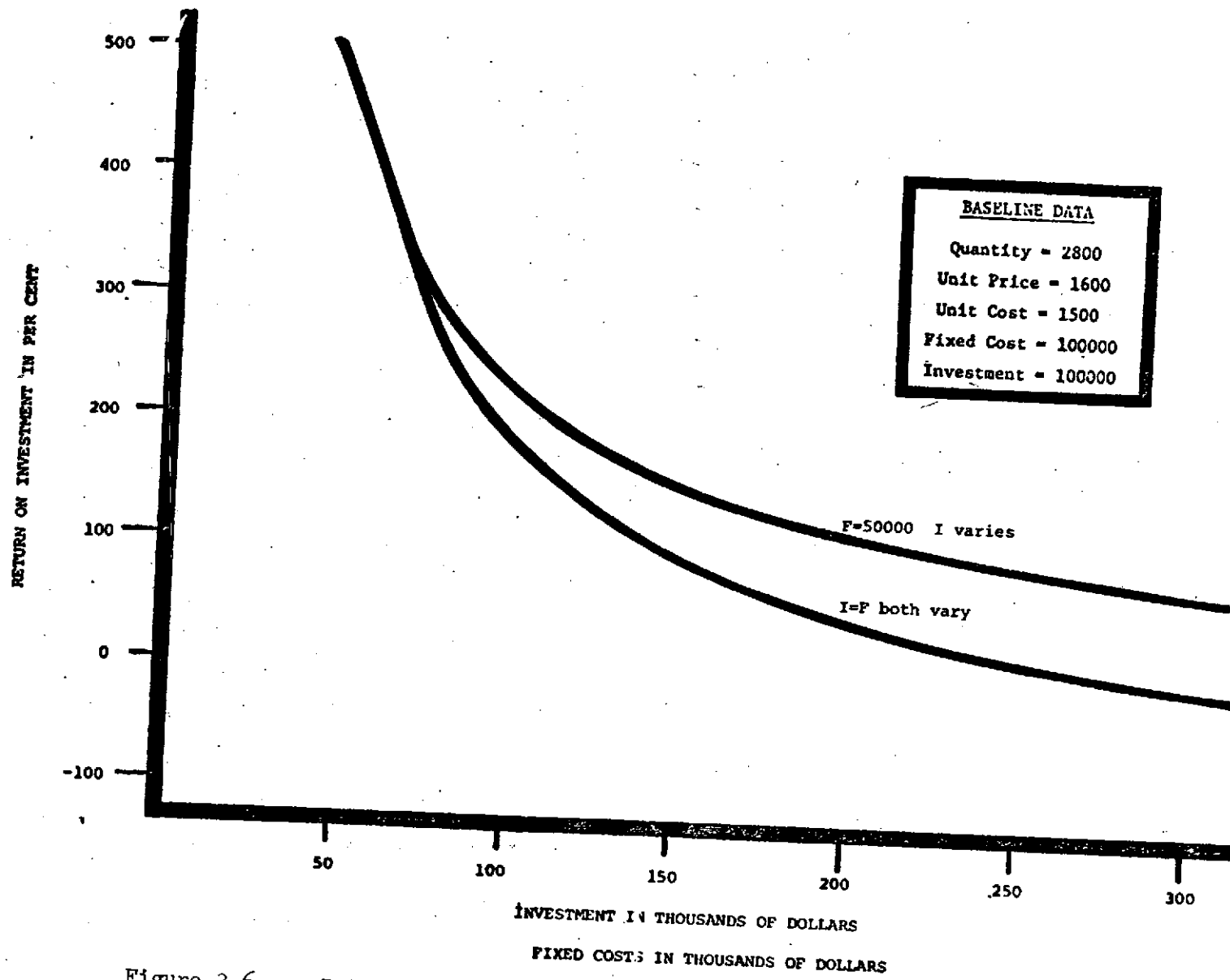


Figure 3-6 Return on Investment vs. Varying Investment and Fixed Costs

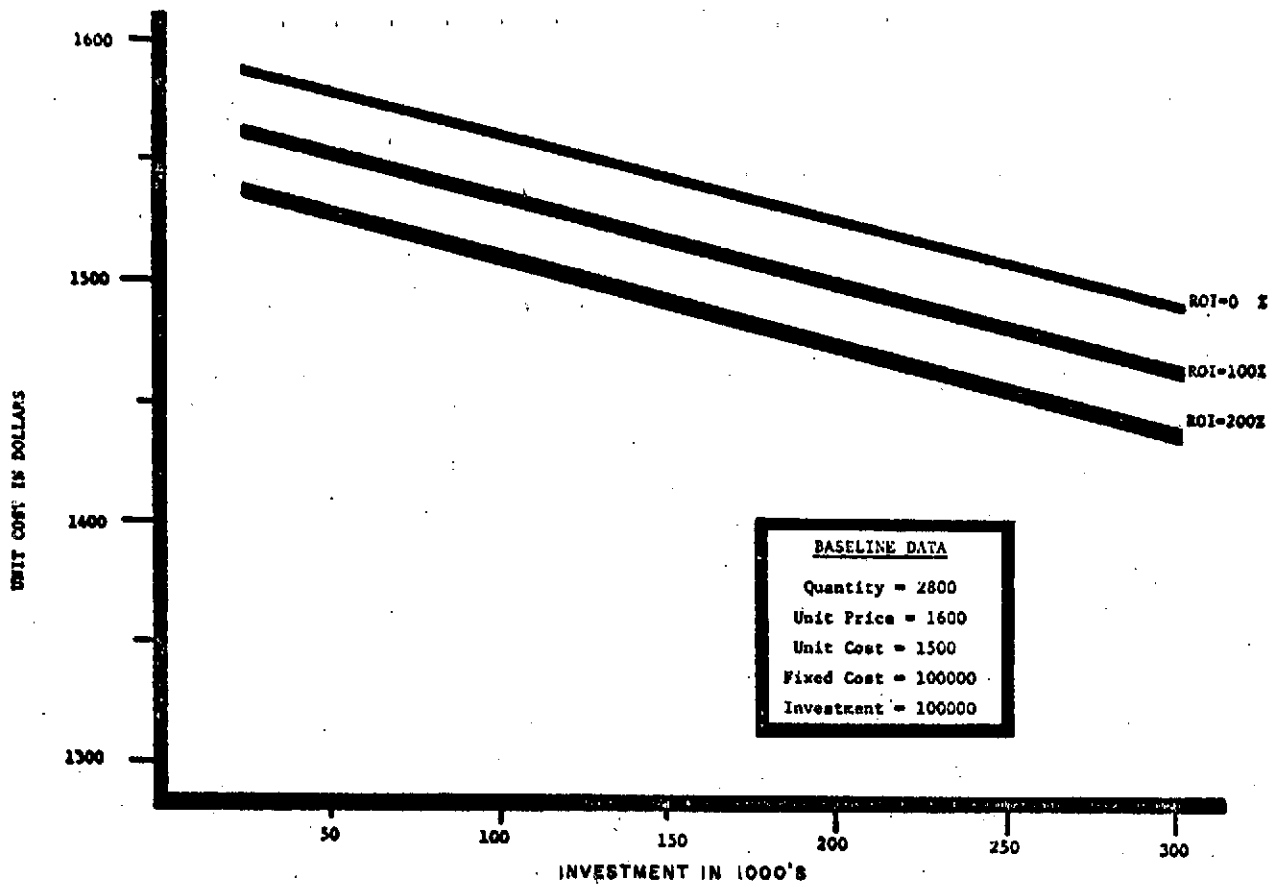


Figure 3-7 Unit Cost vs. Investment

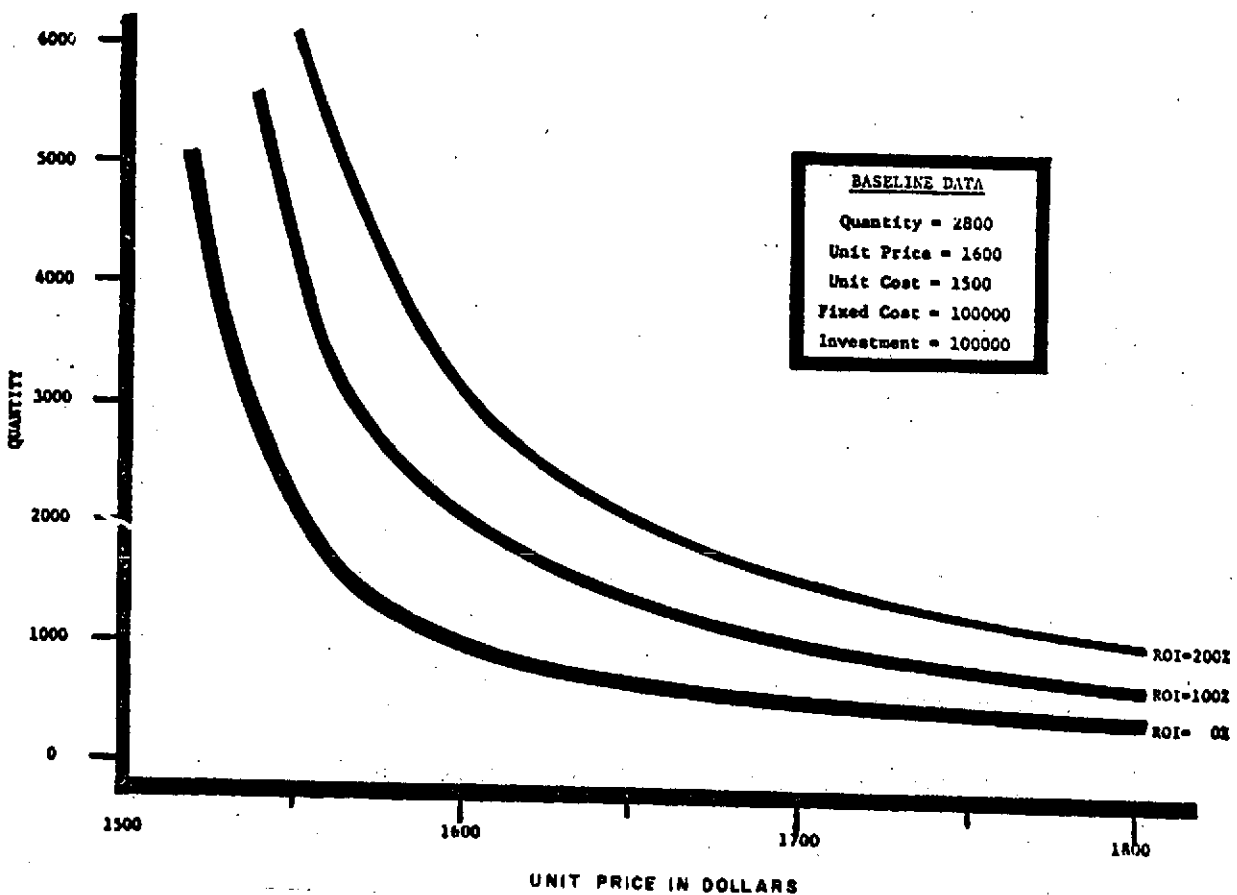


Figure 3-8 Quantity vs. Unit Price

3.2 Screening

As a result of the preliminary screening and evaluation task, ten (10) applications were selected and recommended for further study. The following sections contain the product evaluation charts on the "winners" as well as a brief description of those applications that did not survive the screening.

3.2.1. Recommended Applications

Following is a list of those candidate applications that passed the preliminary screening and evaluation process and were recommended and approved for further study under the conceptual design phase.

<u>Description of Application</u>	<u>Application Code</u>
(1) Solar panels to maintain charge on boat batteries	2 M
(2) Barrier flashers, warning lights for traffic control	2 T
(3) Power supply for CCTV surveillance system	2 S
(4) Power for telephone communication in remote areas	5 C
(5) Power for TV receivers in remote areas for reception of educational programs via satellite	7 C
(6) Standard low power module - portable - forestry communication system	6 G
(7) Solid state anemometer power supply	6 MI
(8) Power supply for instrumentation used to monitor noise pollution	6 EP
(9) Power supply for remote perimeter protection devices	1 S
(10) Solar water pump system	1 IC

An evaluation summary table for these ten (10) application appears on the following pages.

APPLICATIONS EVALUATION SUMMARY TABLE

FACTORS	1 Boat Power Panels			2 Barrier Flashers			3 CCTV Surveillance			4 Remote Telephones			5 Educational TV		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Engineering	2	.5	1	8	1	8	10	1	10	8	1	8	2	1	2
Economic	4	.8	3	7	1	7	10	1	10	8	1	8	2	1	2
Marketing	1	.7	1	12	.8	10	12	.8	7	12	.8	10	11	.8	9
Production	10	.5	5	8	.6	5	7	.6	4	7	.6	4	10	.6	6
Opinion Research	10	1.0	10	8	1	8	8	1	8	8	.7	6	1	.7	1
TOTAL	20			38			39			36			18		

A. Points
 B. Weighting Factor
 C. Total

APPLICATIONS EVALUATION SUMMARY TABLE

FACTORS	6 Forestry Communication			7 Solid-State Anemometer			8 Noise Pollution Monitor			9 Remote Perimeter Protection			10 Solar Water Pump		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Engineering	7	1	7	7	.8	6	3	1	3	1	.8	1	8	1	8
Economic	7	1	7	7	1.0	7	0	1	0	2	1	2	4	1	4
Marketing	7	.8	6	10	.5	5	8	.5	4	8	1	8	9	.7	6
Production	4	.6	2	11	.5	6	11	.5	6	12	.4	5	4	.3	1
Opinion Research	7	.6	4	5	.9	5	0	.9	0	3	.5	2	4	.8	3
TOTAL	26			29			13			14			22		

A. Points
 B. Weighting Factor
 C. Total

3.2.2 Summary of Candidates Not Selected

The following paragraphs provide a summary of the reasons why these candidate applications for solar cells were eliminated from the list of those recommended for the Conceptual Design Study. It should be emphasized that there are many potentially profitable future applications among this list. Many candidates were eliminated only on the basis of the criteria set forth in the NASA requirements for this program, including the requirement for short-term fruition.

3.2.2.1 Power Systems for Ocean Data Stations

Research into remote ocean data systems revealed that the largest dollar expenditures were in stations ranging up to 100 feet in diameter which utilized substantial amounts of power. The stations incorporate batteries and/or diesel generators, which are designed to operate for one year without maintenance. There are, however, many experiments on these stations which in practice require maintenance every one to two months.

The present restricted size of this market and the fact that current work with marker buoys is providing the data required by manufacturers, caused this application to be rejected. Once reliability data is carefully collected from the marker buoys presently under test and presented to developers of data stations, the long range use of solar cells should be quite feasible and widespread. This application now suffers from the lack of sufficient engineering data that could convince developers that, cost-wise, solar cells are practical.

3.2.2.2 Navigational Aids, Beacons, Channel Markers and Small Buoys

This application is an excellent example of the use of solar cells in solving terrestrial problems. However, since active work is now being performed by solar cell manufacturers, coupled with the fact that the Coast Guard is experimenting with prototype models of solar powered buoys, this application was eliminated in order to avoid duplicating current activities.

3.2.2.3 Emergency Radio Telephones for Marine Use

Applications of solar cells to power VHF radios in both recreational and commercial boats is entirely feasible, and the market for solar powered radios definitely has potential. However, another selected application using a systems approach that maintains the charge on the boat battery provides both power for emergency radio telephones and other desirable features such as powering several running lights. In some instances, emergency power could be accumulated from solar arrays for starting engines. The communication application is so specialized that the broader application of boat battery recharging demonstrated greater appeal. Therefore, this specific application was rejected in favor of the selected marine battery recharging application.

3.2.2.4 Remote Sensors Used for Traffic Counting and Control

The application of solar cells for remote sensing depends primarily on the ability of transportation departments in local and state governments to act in reasonable response time to accept new and innovative systems. Although needs exist in this area, this application was rejected because of the probable extensive time required to bring it to practice. Some problems involved with using solar cells for traffic counting involve the ruggedness of the package and the cost of coupling the sensor to a transmitting device. Also, the corresponding receiving and data processing system presents budgetary problems.

3.2.2.5 Power Supplies for Air Crash Rescue Beacons

A major problem in attempting to locate downed aircraft is the inability of search and rescue operations to quickly locate the crash site. Present specifications for rescue beacons are very stringent and, of course, must be inexpensive so that they can be incorporated in general aviation as well as commercial and military aircraft. Extensive R and D expenditures in the engineering packaging of the solar power system that would guarantee survival of the unit following a crash, and the fact that the array orientation cannot be guaranteed, have caused this application to be rejected. In addition,

the crash site could be shielded by mountains and tree shadows, thereby reducing the effectiveness of the solar array. On the positive side, present batteries used in powering the beacons do run down. Studies of FAA statistics on crash survival indicate that many pilots and passengers survive after their beacon has stopped operation and that a continuing and rechargeable source of power would be desirable. Specifications regarding the basic rescue beacon are still being revised. Because of the lack of firm specifications and the engineering time and cost uncertainty, this application was eliminated from the catalog list.

3.2.2.6 Power Systems for Remote Aircraft Landing Fields

This application was rejected because most remote aircraft landing fields require power not only for navigational instruments, but for lighting systems. The amount of power required for these lighting systems is substantial, and the size of the array was judged to be too costly for this application, at this time.

3.2.2.7 Power for Obstruction Monitoring Devices for Railroad Tracks

There is a need for devices to monitor track conditions and to detect obstructions in the path of railroad trains. It is expected that requirements will increase as more emphasis is placed on high speed trains. However, these train systems are still in the test phase, and substantial use of high speed trains is not anticipated within the next five to ten years. Although there are present needs for devices of this type, the budgets and financial conditions of the railroads at this time do not permit R and D of this nature.

3.2.2.8 Power for Automatic Railroad Car Identification Systems

There is a need in the railroad industry for a system to locate and identify railroad cars. Presently there are large numbers of railroad cars that have been interchanged between the various companies, placed on sidings of railroad yards, and are not accounted for. Since these cars cannot be dispatched, they represent substantial loss to the owning company. The system for

identifying railroad cars would basically consist of a passive device located in each car, a sensing device mounted in the railroad bedway powered by a small solar array, and a data processing system to accumulate and display the required information. Again, the reason for rejecting this application was primarily the fact that the railroad companies do not have adequate budgets for developing a device of this type.

3.2.2.9 Battery Charging Systems for Campers and Motor Homes

There is a need to provide quiet power for campers and motor homes, since their increasing widespread use in recreational areas causes a disturbance for other campers. Upon investigation, it was revealed that the amount of power consumed by typical vehicles is substantial, since their owners' mode of living is often translated from the home to the motor home or camper. Persons owning these vehicles are therefore using television sets and other appliances which consume substantial amounts of power.

Manufacturers of motor generators specifically designed for motor homes have devoted considerable effort to reducing the noise of their generators through the use of various insulating materials. In tests, it was judged that these systems have effectively solved the problem of engine cooling while reducing the noise level to an acceptable level.

3.2.2.10 Solar Arrays for Minimal Power for Remote Cabins and Campsites

A large number of respondents listed this application as a possibility due to the increasing numbers of campgrounds and campsites and the cost of installing, operating and maintaining long power lines. Environmental consequences also need to be considered. However, the cost factor of providing an array large enough to satisfy the minimal demands of users of such campsites and cabins was judged to be too great.

3.2.2.11 Recharging Systems for Nighttime Illumination of Ski Areas

From an economic standpoint, the extension of services at night for owners of ski areas represents a real advantage. Illumination of many areas would also

increase the use of recreational lands. However, even with the most efficient lighting systems, the array size is large and the cost prohibitive.

3.2.2.12 Temperature Monitoring of Livestock

This candidate represented a unique application of solar cells to power a device which measures the temperature of livestock in cattle feed lots. Sick animals in feed lots can affect other animals at a point when the maximum investment has been placed in the feeding of the livestock. In this application, a small inexpensive temperature sensor and a very small and simple transmitter would be attached to the ear of the animal. A signal would be transmitted 50 to 75 feet to a receiver when the temperature of the animal exceeded a preset limit. The use of solar cells would be limited to several cells, and the problem of survival of the cell is certainly an important consideration. The packaging would have to be extremely rugged.

The overall usage of solar cells in this application was judged to be not of sufficient magnitude in comparison with the cost of development and marketing, and this application was therefore rejected.

3.2.2.13 Wildlife Tracking Transmitters

This candidate was first disclosed during a previous study, and was the basis for the livestock temperature monitoring application described in the preceding paragraph. In this application, a miniature solar powered transmitter would be attached to a wild animal for tracking purposes. It was rejected for the same reasons as the temperature monitoring application.

3.2.2.14 Solar Cell Power for Wireless Intrusion Sensors

The need for increased and improved security devices has received widespread attention, particularly in view of increasing crime rates and the public awareness of this threat. The use of solar cells in this application would be to power a small FM transmitter which is attached by a suction device to a window or wall. The device would generate an alarm should a window be broken

or a wall tampered with. The device would transmit back to a receiving station at the location and could in turn be coupled by automatic dialing systems to the central alarm headquarters. The advantages of this system would be that installation costs would be minimal as compared to present systems wherein the installation costs can be a major portion of the overall cost of the security system. False alarm rates are the most serious problem in this type of system.

The use of a solar cell to furnish power to the device would be feasible in that most of the transmitters would be placed on outside windows which receive direct sunlight. The lack of sophistication of many burglar alarms and intrusion protection companies was reflected in the survey conducted during the course of this study. This application was judged to be still feasible but not a short range, large user of solar cells. A substantial amount of application data, advertising and general education regarding solar cells would be required for this application.

3.2.2.15 Alarms for Protection of Remote Communications Equipment

There is a need for a solar powered alarm system that would operate independently of the primary power supply in remote installations of communications equipment such as microwave relay stations. This system could be used to signal the central station in the event of intrusion at the remote site, or in case of a power failure. This application was eliminated from the recommended list because of the limited size of the market and the length of time required to develop a practical system.

3.2.2.16 Power Supply for Remote Access Controls and Guard Stations

The need for increased perimeter protection, particularly with large companies, and in border access has created the need for powering guard stations in a reliable way so that the power cannot be interrupted either accidentally or purposely. However, many of these guard stations are presently using radio equipment which is recharged when guards are changed. Most respondents replied that they would like to have perimeter lighting around these stations.

However, typical power requirements for such lighting are 200 to 500 watts and represent, at this time, economic justification for rejecting this particular application.

3.2.2.17 Monitoring Equipment to Test Water Supplies Against Contaminants and Poisons

Many governments are concerned with the possibility of contaminants being introduced either accidentally or purposely into a municipal water supply system. There is a need for monitoring or sensing stations in various locations along the water system that would activate suitable telemetry equipment and signal when a contaminant is detected. Of particular concern, of course, would be drugs such as LSD, which are not now eliminated by normal filtration and purification methods. Although this application could offer widespread use of solar cells, since the testing points would be in numerous isolated locations, the proper test methods have not been fully developed. It appears that another two to three years will be required before reliable equipments are designed that would eliminate or guard against this hazard.

3.2.2.18 Land Based Emergency Radio Telephones for Motorist Assistance

There is a present need for emergency roadside telephones on freeways and interstate highway systems which would allow motorists to call for assistance. Many cities have already incorporated systems of this type. The power and installation costs for these systems are substantial. Numerous approaches have been taken, including a generator type telephone which transmits an RF signal. There are a few installations in the East that are powered by solar systems.

Investigation into this application revealed that present maintenance of a telephone is far from adequate and a large percentage of the units are inoperative due to dust, vandalism and physical damage caused by other maintenance workers' equipment. There is, however, commercial power available in a large percentage of these locations which definitely competes with the solar cell approach. Also, the cost of the transmitter has not yet been reduced to competitive prices, and the ability of the system to reliably

receive calls is in doubt. This application, however, definitely merits further study, as a potential future application of solar cells.

3.2.2.19 Fire Reporting Radio Telephones for Wilderness Areas

The solar power system coupled with a radio telephone transmitter is an ideal application of solar cells, since most fire reporting phones are located in remote areas. However, forest rangers report that vandalism is a very serious problem. Rangers must keep most fire reporting telephones locked, and they are therefore used only by forest service personnel. This situation seems to be prevalent in most of the national parks and forests. The vandalism problem, in terms of the system package design, and the fact that the budgets for forest activities are being allotted to other areas, caused this application to be rejected from the prime list.

3.2.2.20 Power Supply for Unattended Radio Base Station Repeating Installations

The increased use of mobile communications has created the need for base stations that service radio repeaters in most of the major cities in the United States. Power to these installations is a problem, since they are located on high mountain peaks and remote locations. However, most of the major cities have at least one or two of these base stations presently operating, and have already solved the problem of power. Additional installations therefore can use the same power source. Lack of a competitive advantage eliminated this application.

3.2.2.21 System Power for Isolated Fire Lookout Towers

Fire lookout towers presently require power for communications, instruments and ranger living accommodations. In some cases, power lines run to these towers along with telephone lines. The towers also have their own independent systems, using both diesel and gasoline generators. It appears that the construction rate for fire towers will be minimal; therefore, large scale application of solar cells is restricted, since the growth rate is small and the economics of replacing existing systems is not apparent.

3.2.2.22 Lifeguard Communication Systems

Lifeguard towers must maintain communications with a central location that dispatches rescue vehicles. Most of these lifeguard towers are now wired for telephone service. This application was rejected because of the vandalism problem, coupled with the fact that most lifeguard services have minimal budgets for their operations.

3.2.2.23 Power Systems for Seismic Detectors

There are numerous programs in various areas of the world subject to earth tremors that are attempting to provide a network of detectors to sense or predict the occurrence of the earthquakes. Presently prototype systems are being installed along the San Andreas fault in California and other major fault lines in Japan. Much research is being done to this area; however, the type and numbers of units do not offer an adequate market potential for consideration at this time.

3.2.2.24 Power System for Rainfall and Snow Level Recorders

There is a requirement for rainfall, snow and stream level monitoring in National Forest areas. These systems would be tied to a telemetry system and a central data collection system. There are systems in use, primarily powered by batteries, which now provide this function. Again, the total market potential for devices of this type is small; however, this application led to the consideration of a standard power module that could be used for a variety of applications in the forestry system, this particular application being one. This standard module has been added to the recommended application list.

3.2.2.25 Airport Wind Direction and Speed Sensors and Transmitters

There is a need to alert general aviation pilots as to the wind direction and speed while approaching isolated airports. This information would be visually

presented by mechanical means, together with lights. During conversations with Federal Aviation Administration authorities, it was determined that the installation and use of such devices and any allocation of suitable frequencies appears to be a number of years away. Therefore, this should be considered as a long range rather than a short range application.

3.2.2.26 Ground to Aircraft Wind Speed and Direction Transmitters

Development of a complete system to alert pilots of wind speed and direction is being considered by the F.A.A. but is still in long-range planning. The lack of allocation of operating frequencies and the fact that ground winds and speeds are only a portion of the data which pilots need have resulted in rejection of this application.

3.2.2.27 Command/Control System for Water Supply Distribution Systems

There are a number of municipalities and governments which depend on numerous sources of water to supply their total demand. The water sources are wells, streams, and rivers that need to be controlled by means of automated systems. The sensors to provide the necessary automation are located by necessity in remote locations where they sense the supply level, rate of flow, and other parameters. Meetings with officials in the water systems control field, revealed definite requirements for systems that are powered by reliable and independent sources. However, the total market for solar supplies in this area is small but should grow within the next five to ten years.

3.2.2.28 Control Systems for Monitoring Stream, Lake and Reservoir Levels

There are telemetry systems presently being used which incorporate sensors located in streams and reservoirs that provide data as to the water levels and flow rates from these sources. The rate of construction of new reservoirs is somewhat limited and the present control systems appear to be adequate unless a very inexpensive replacement system can be devised. Lack of economic justification was the primary reason for rejecting this application.

3.2.2.29 Recycling of Sanitary Facilities in Recreational Areas

There is a need, due to the increased use of campgrounds, to provide both mechanical and electrical recycling of sanitary facilities of both solid and liquid waste materials. Again, vandalism is a problem in any system located outside. Also, it was the opinion of several authorities in this field, that an exposed array could present an attractive target for rifle and pistol enthusiasts.

3.2.2.30 Water Purification System Powered by Solar Cell Panels

There is a need in many locations to provide systems to purify the water supply. Solar cells would power the necessary filter and chemical maintenance devices which add the supplies to the system. The amount of power required ranges between 2 and 10 kilowatts. Economic factors again gave cause for rejection.

3.2.2.31 Supply to Power Automatic Controls in Chemical Plants

Many large chemical plants require reliable sources of power. In the event of power failure, batches of material could be ruined if equipment such as mixers, strainers and cookers are stopped in process. In some cases, this could represent a loss of several million dollars. These companies also face security problems which have created both accidental and premeditated interruption of power. However, the large amount of power required and the economics of a solar power array caused this application to be rejected.

3.2.2.32 Air Pollution Sensors in Telemetry Equipment Located in Remote Areas

The use of low power air pollution sensors coupled to transmitters is increasing at a rapid rate. Research into this area revealed that many of these sensors are located near urban areas, since it is in these areas that pollution is most likely to exist. Respondents who are actively engaged in air pollution research indicated a low acceptance level for a solar powered device. The primary reason was that many of these sensors use recorders from which the information is collected only periodically and is not needed in real time.

3.2.2.33 Water Pollution Sensors and Telemetry Equipment

The need for water pollution sensors has received increased emphasis because of water quality enforcement, and it appears that a substantial market will develop for sensors of this type within the next two years. The amount of power required for the sensors is reasonable and can be supplied adequately by a small solar array. However, a large number of pollution sensors which will be in use within the next three or four years have already been designed which incorporate a small battery or other means of supplying the power. Again, those involved in pollution research indicated a low level of acceptance to a solar cell power system.

3.2.2.34 Emission Monitoring Instruments for Smoke Stacks

There is a need to attach instruments directly to smoke stacks for monitoring the level of pollutant emissions. Many of these smoke stacks are quite tall and the power run up the stack presents installation problems. However, elements of the emitted pollutants could cover the solar panel array, thereby greatly reducing its efficiency. This fear was expressed by several respondents in this area.

3.2.2.35 Sensors for Detection of Air Radioactivity

The level of radioactivity is being monitored at numerous sites throughout the United States and overseas. Sensing of radioactivity not only involved detection of nuclear tests and their effects, but instrumentation used to establish background radioactivity for various scientific experiments. Sensors presently being used are powered by small batteries which are periodically changed. The small potential size of the market was the prime consideration in rejecting this application.

3.2.2.36 Emission Monitoring Instruments for Automobiles

There is a need for instruments located on an automobile which are independent

of the automobile power system to provide a record of the emissions emanating from a vehicle, as well as the length of time which the automobile operates, in order to determine when maintenance should be performed on the emission control devices. The use of solar cells appears to be practical. However, the possibility of incorporating such devices is estimated to be five to seven years away, thereby placing this application in the long-range list.

3.2.2.37 Emergency Power Systems

Emergency power systems are provided in nearly all hospitals for lighting and other critical facilities in the event of commercial power failure. Emergency power facilities are required for many computer systems where a power failure could result in costly miscalculations or time lost. There is a need also for emergency lighting and power in high rise office buildings. Analysis of these applications indicated that the use of solar power at present would not be economically competitive with existing systems.

3.2.2.38 Power Systems for Oil Drilling, Ocean Platforms and Barges

There are a number of solar powered systems presently in use on off-shore ocean platforms. This application was carefully studied to determine the acceptability and market size. Special configurations of solar panels, rather than a standard design, are necessary for large scale acceptance in this marketplace. It was determined that in the last several years, there has not been a large increase in the number of off-shore platforms. However, with the new emphasis on energy resources, the number of platforms is increasing. This represents a relatively large scale use of solar power but has not been recommended in the select list since sales are presently being conducted in this marketplace, and a duplication of effort was not in line with the objectives of this study.

3.2.2.39 Power System for Portable Power Tools

A number of respondents in the construction industry indicated that a source of power during the initial phase of construction is quite important and that there were problems with existing rotating engine type supplies. However,

the amount of power required for typical power tools ranges from 1 KW to 20 KW. This represents an economic acceptance barrier.

3.2.2.40 Solar Cell Battery Charging Systems for Outdoor Billboards

The cost of installing and maintaining outdoor illuminated billboards is a continuing problem to the advertising industry. The size of the solar array would have to be quite large, since the primary function would be to provide illumination. Secondly, the number of outdoor billboards is decreasing because of increased pressure from environmentalists. Advertisers are going to other forms of billboards, such as inside displays in shopping centers.

3.2.2.41 Point-of-Purchase Temporary Displays

This application concerns power for advertising displays in supermarkets and department stores where a commercial power outlet plug is not readily available or, if used, would present a hazard to customer traffic. The small motors typically used in these displays can be operated from small sources of power. In this application, solar cells would convert indoor incandescent lighting to power for the motor. However, the cost of these displays is generally kept to a very low level since they are supplied as promotional giveaways. The cost of the solar power system would be a major portion and would, again, represent an economic barrier.

3.2.2.42 Solar Energy Scientific Experimentation Kit for Students

This application received a very favorable response from science and physics teachers in the academic community. The overall response placed this application very high; however, the cost that the users would be willing to pay is quite low considering the present cost of solar cells. This application does, however, serve to educate and promote the use of solar energy in a very specific way. The long term value could be significantly beneficial.

3.2.2.43 Standard Medium Power Module - Fixed Installation

A number of standard modules were considered to fill a wide range of applications. In this instance, a module generating approximately 500 watts would be supplied to various industries such as the forestry service, construction industry, and communications equipment industry to provide a reliable source of remote power. Development of exact standard requires additional research so as to optimize the proper design and configuration of the unit. Economic considerations as opposed to the market size were the prime reason for rejecting this application.

3.2.2.44 Standard Medium Power Module - Transportable

The advantages of a transportable standard module capable of generating approximately 500 watts of power would be in the versatility of its use with a wide variety of portable communications equipment. Problems associated with transportable units are proper orientation and the ruggedness of the package. Again, the size of the device and its corresponding cost make this a marginal application, until solar cell production costs are reduced.

3.2.2.45 Standard Low Power Module - Fixed Installation

The amount of power generated by such a module would be in the order of 100 watts in a fixed location, to power communications, meteorological, and a variety of other equipment where this amount of power is required. This application was rejected in favor of a standard portable module designed specifically for forestry work.

3.2.2.46 Standard Medium Power Module - Sun Tracking Type

A 500 watt module that incorporates solar tracking capability would minimize cost per watt by optimizing the array orientation. This device did not receive the expected reception, primarily because of the cost and anticipated low reliability of the tracking mechanism. However, the tracking mechanism would represent the smaller part of the total system price if a larger power system were used.

3.2.2.47 System for Automatically Dispensing Insecticides

There is a need in the agricultural industry to provide automatic dispensing of various chemicals in the irrigation water supplies. The effectivity of insecticides can be enhanced if a continuous rather than a single, large application of the chemicals is provided. This application rated very high and the dispensing mechanism required approximately 10 watts of power. Commercial power is seldom available at the points which are optimum for the dispensing of the chemicals. The trend toward automation in the farming industry could make this a practical application. However, the size of the market has not been clearly defined at this point and it appears that the dispensing mechanisms require a substantial amount of R and D.

3.2.2.48 Sewage Processors and Digestors

There is a need for additional processing and digesting units for sewage systems, particularly in view of increased enforcement of water quality standards. Often times it is now necessary to process sewage at the exit location, which could be remotely located. The types of processors and digestors being developed, however, utilize 500 watts to 2 KW of power and the cost of these is being trimmed to the lowest possible levels. In addition, the market size appears to be limited to approximately 100 installations by 1976.

3.2.2.49 Solar Gravity Motor and Water Pump System

Several experimental models of gravity and direct conversion solar power systems have been constructed as laboratory prototypes. This system has a potential of using both thermal and direct energy, and the combination of the two could complement each other to produce a reliable power source. The amount of research and development required to develop a satisfactorily operating and economic system would appear to take 3 to 5 years. This has been cataloged as a long-range application of solar cell technology.

3.2.2.50 Cooking Devices Utilizing both Thermal and Direct Energy Conversion

This application is primarily designed for developing countries and makes uses of solar concentrators to provide both thermal, heating and direct energy conversion devices to the cookers. Military, outdoor camping and recreational industries have need for products of this type. The amount of power required, and the length of time for development of practical systems place this application in the long-range list.

4.0 CONCEPTUAL DESIGN STUDY

4.1 General

The preliminary screening and evaluation effort described in Section 3.0 culminated in the selection of ten solar cell applications recommended for the conceptual design study. The results of the conceptual design study were submitted to NASA, and after discussions with NASA personnel, three of the recommended applications were replaced. Conceptual design studies were then completed for the three replacement applications.

The original ten selected applications were:

<u>Description of Application</u>	<u>Application Code</u>
(1) Solar panels to maintain charge on boat batteries	2 M
(2) Barrier flashers, warning lights for traffic control	2 T
(3) Power supply for CCTV surveillance system	2 S
(4) Power supply for small refrigeration unit	3 MV
(5) Power for telephone communications in remote areas	5 C
(6) Power for TV receivers in remote areas for reception of educational programs via satellite	7 C
(7) Combined solar and wind generator	2 AG
(8) Meteorological instrumentation	4 MI
(9) Standard low power module - portable	6 G
(10) Solar water pump system	1 IC

Application numbers (4), (7) and (8) were subsequently replaced by:

<u>Description of Application</u>	<u>Application Code</u>
(4A) Solid state anemometer power supply	6 MI
(7A) Power supply for instrumentation used to monitor noise pollution	6 EP
(8A) Power supply for remote perimeter protection devices	1 S

Also, as a result of discussions with NASA, Application (9) was modified to a specific application for forestry communications equipment rather than a general purpose module.

The conceptual design and final evaluation phase of the study called for the following:

1. A functional block diagram indicating the functional relationships of the components in the system and of the system with interfacing systems, if pertinent.
2. Performance specifications and requirements of the system and of each of the components.
3. Overall dimensions and weight of the system and the major components.
4. Unit cost of the system.

Upon completion, a detailed evaluation of the attractiveness of each of the selected applications to potential users was made, according to the methodology and criteria formulated earlier.

4.2 Ten (10) Selected Solar Cell Applications

This section contains detailed descriptions and conceptual designs for the final ten solar cell applications submitted to and approved by NASA personnel. The 10 applications described herein are:

<u>Description of Application</u>	<u>Application Code</u>
(1) Solar panels to maintain charge on boat batteries	2 M
(2) Barrier flashers, warning lights for traffic control	2 T
(3) Power supply for CCTV surveillance system	2 S
(4) Power for telephone communication in remote areas	5 C
(5) Power for TV receivers in remote areas for reception of educational programs via satellite	7 C

	<u>Description of Application</u>	<u>Application Code</u>
(6)	Standard low power module - portable - forestry communication system	6 G
(7)	Solid state anemometer power supply	6 MI
(8)	Power supply for instrumentation used to monitor noise pollution	6 EP
(9)	Power supply for remote perimeter protection devices	1 S
(10)	Solar water pump system	1 IC

4.2.1

APPLICATION 1

Solar Panels to Maintain the Charge on Boat Batteries (Code 2 M)

1.0 DESCRIPTION OF THE SYSTEM

The system consists of a solar panel mounted to the superstructure of a boat used for either commercial or recreational purposes. The solar panel would maintain the charge on the boat's battery when the boat is unattended. The system would replenish the charge lost due to normal battery internal leakage and, in addition, provide power for emergency communications should the battery and/or engine fail altogether. The system can also provide the additional power so that an alarm system and night light can be left on at all times inside the boat cabin to help prevent thefts.

2.0 SYSTEM REQUIREMENTS

The system consists of a solar panel directly charging a standard marine battery. We anticipate that the retail price of the unit will be \$195.00. It is important to note that the panel life is equal to that of the boat. Therefore, the high first cost can be justified. Research indicates that the solar panel size must be kept to a minimum. A size of approximately two square feet is considered the maximum acceptable size for most types of boats. It is anticipated that this size will generate approximately 0.5 amps. For sailboats, the solar panel must be packaged in a rugged manner so it can withstand the weight of a 250-lb. man. For power boats, the standing weight requirement is less severe. The unit must be capable of being firmly bolted to the boat in order to prevent theft. A 12.0 volt system is most desirable along with a method for easily removing and replacing the solar panel for maintenance of the boat (painting, etc.). The solar panel system might also have a removable feature so that the unit could be used on islands and remote docking sites.

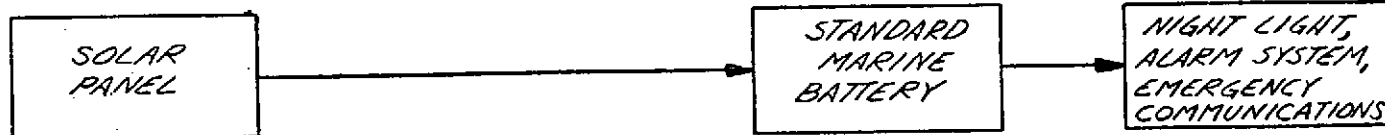
3.0

ADVANTAGES AND DISADVANTAGES

The advantages of the solar system are as follows:

1. Has the potential for reducing the scope of many search and rescue operations, saving both lives and money.
2. The boat battery is always kept in a fully charged and operational condition.
3. The battery life expectancy is increased since the battery is seldom discharged.
4. Allows a small light to be left on to keep the inside cabin dry.
5. Provides power for emergency communications.
6. Provides additional electrical power with low maintenance.
7. For sailboat owners, the noise of an engine can be objectionable.
8. New innovative devices are always in demand by boat owners.

The major competitive disadvantage, besides economic, is that commercial power is typically available at many dockside marinas. Secondly, the unit may be difficult to mount and install due to severe space limitations on boats. Theft is also a problem with expensive marine accessories.



0.5 AMPS, 12V
 12 IN x 24 IN x 2 IN
 (31 CM x 61 CM x 5 CM)
 APPR. 5 LBS (2268 G)
 \$ 195⁰⁰
 MOUNTED
 TO SUPERSTRUCTURE

60 AH, 12V
 9 IN x 14 IN x 10 IN
 (23 CM x 36 CM x 25 CM)
 30 LBS (13.6 KG)
 \$ 40⁰⁰
 STANDARD BATTERY
 MOUNTING & LOCATION

1.6 AMP-HOURS PER
 DAY MAX LOAD

SOLAR PANEL TO CHARGE A
 BOAT BATTERY (CODE 2M)

4.2.2

APPLICATION 2

Barrier Flashers, Warning Lights for Traffic Control (Code 2 T)

1.0 DESCRIPTION OF THE SYSTEM

The system consists of a solar array encapsulated into the top of the flasher light, mounted to the surface of a portable or transportable warning barrier, plus a rechargeable battery. The new federal and state standards, are being strengthened considerably more than anticipated, with the result that present barrier flashers will no longer meet the illumination requirements. The lamps used in most barrier flashers today will not provide sufficient illumination to meet the new standards. Therefore, flashtubes are being considered in the new design. This requires electronic circuitry and transformation of the battery voltage to a much higher value for triggering the flashtube. The system would supply sufficient power to fully recharge the flasher battery during daylight hours. Since battery life would be greatly extended, battery replacement costs and maintenance costs for barrier flashers would be considerably reduced.

2.0 SYSTEM REQUIREMENTS

The solar powered barrier flasher system is projected to cost approximately \$50.00 in small quantities. It is a more sophisticated, higher quality product and will not be in direct price competition with the inexpensive types being marketed today. The entire flasher unit must be of rugged packaging design in order to withstand the rough handling they will be subjected to at construction sites and in transit. Colored gas tubes are available. Thus, the entire flasher unit can be clear with the solar cells set into a flat crown on top. The diameter of the crown is approximately 8" (20.3cm). The solar panel should be capable of supplying about 100 ma at 12 volts. The flasher unit should be designed so that removal from the surface of the barricade requires a special tamper-proof tool. The required operating temperature ranges between -25°F (-31.6°C) and +120°F (+48.8°C). The conversion efficiency of the power pack transformer is approximately 50%.

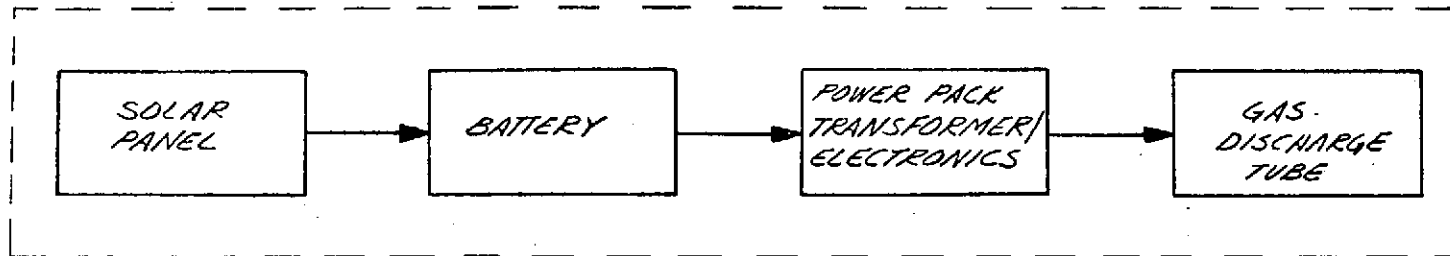
3.0 ADVANTAGES AND DISADVANTAGES

The advantages of the solar powered barrier flasher are:

1. Improved safety as the result of reduced probability of battery failure or....
2. Improved safety because of higher intensity lights required by new federal and state statutes.
3. Maintenance and service costs are reduced because of reduced frequency of battery replacement.
4. Can be used in remote, rural areas, where periodic maintenance is costly.

One disadvantage is that in very bad weather, when the flasher is needed during the day as well as at night, the power output available from the solar array will be low. Also, the likelihood of placement in tunnels and heavily shaded areas is high. Theft and vandalism are also obvious problems.

SELF CONTAINED UNIT



12V, 0.1 AMP
50 IN² (323 CM²)
1 LB (454 G)
\$10⁰⁰

12V, 6 AH
7 IN x 3.6 IN x 5 IN
(18 CM x 9 CM x 13 CM)
7 LBS (3.2 KG)
\$20⁰⁰

12V, 0.06 AMPS
2.5 IN x 2.5 IN x 4 IN
(6.4 CM x 6.4 CM x 10 CM)
1 LB (454 G)
\$14⁰⁰

400 V, 13 WATT-SECONDS
60 FLASHES PER MINUTE
\$2⁵⁰

SOLAR POWERED
BARRIER FLASHER AND
WARNING LIGHT
(CODE 2T)

4.2.3

APPLICATION 3

Power Supply for Closed-Circuit Television Surveillance System (Code 2 S)

1.0 DESCRIPTION OF THE SYSTEM

The system combines a solar power supply with microwave CCTV surveillance equipment. A solar panel array would recharge the batteries used to operate TV surveillance cameras and microwave transmitting equipment used in a variety of applications. As an example, in the construction industry, cameras of the new low light level type would be installed in strategic locations at the construction site for continuous monitoring during those times when workmen are off duty, thereby reducing the growing problem of theft. The video information from the cameras would be transmitted to a central monitoring station via microwave link. Monitoring could be accomplished visually, or automatically by means of a video memory storage and image comparison system which would initiate an alarm signal if a change occurred in the scene monitored by the camera. The system can also be used for personnel and vehicle intrusion detection, inventory control and fire detection.

2.0 SYSTEM REQUIREMENTS

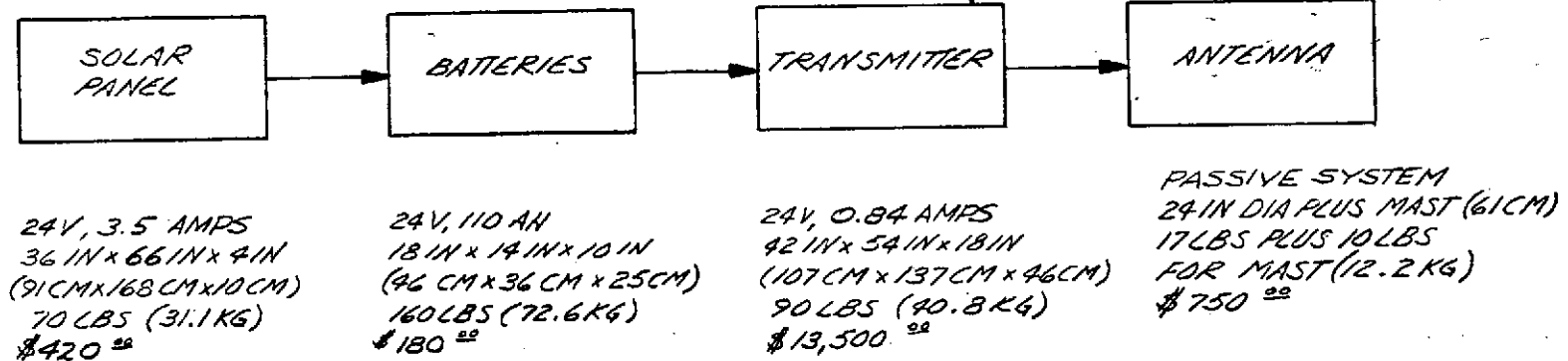
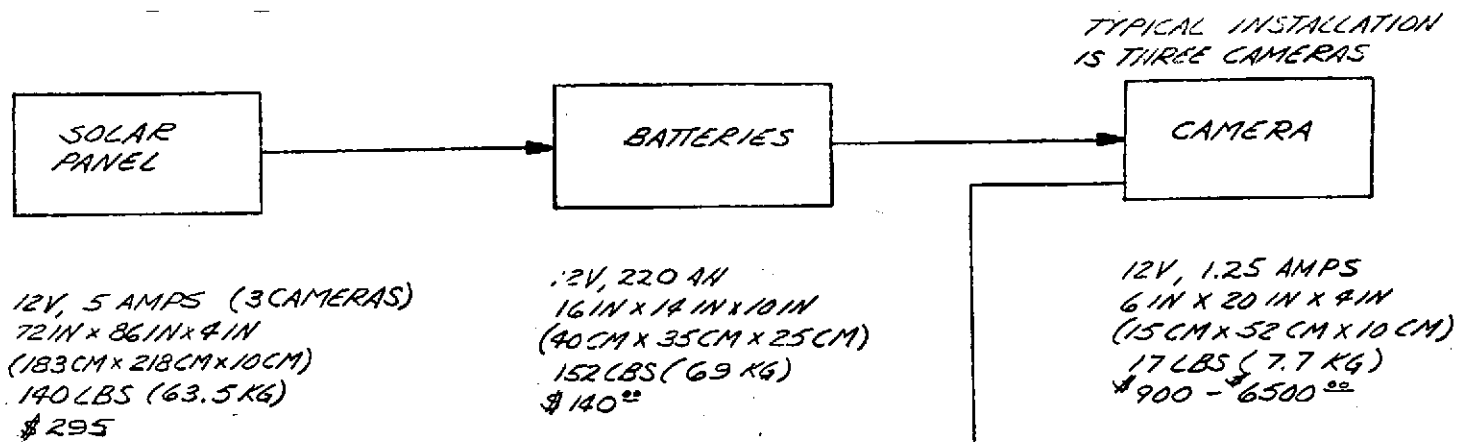
Two distinct solar power systems are required to provide power for the CCTV Surveillance System because the camera portion is a 12-volt system while the microwave equipment operates on 24-volts. A typical installation is three (3) cameras, with the camera cost ranging from \$900 to \$6500 each. The price differential is determined by the required light sensitivity. A 5 amp solar panel costing around \$295 is required to power the cameras. The panel designed to power the microwave equipment will generate approximately 3.5 amps and costs \$420. The panels should be designed for ease of installation and removal with special tamper-proof tools. The same applies to the LLLTV cameras. A typical location for the equipment and the solar panels would be near the top of the tower crane used in construction of commercial buildings.

3.0 ADVANTAGES AND DISADVANTAGES

Advantages of the solar powered CCTV surveillance system are:

1. Self-contained power source is more difficult to disable without detection.
2. Combination solar/battery power makes the system independent of commercial power source and the large line transients created by heavy-duty equipment.
3. Substantially reduces--and in many cases--eliminates the need for security personnel.
4. Visual monitoring simplifies the problem of providing correct and sufficient response to each situation (i.e., fire, vandals, single prowler, etc.).
5. In the construction industry, portable electronic equipment is easy to relocate as construction progresses and is readily transportable between sites.

Disadvantages, in addition to relatively high initial cost, are the size of the solar arrays and susceptibility to damage. Also, necessary permits are required for allocation of operating frequencies.



SOLAR POWER SUPPLIES FOR CLOSED
CIRCUIT TELEVISION SURVEILLANCE SYSTEM
(CODE 25)

Power for Telephone Communications
in Remote Areas
(Code 5 C)

1.0 DESCRIPTION OF THE SYSTEM

This system consists of a medium size solar power supply and batteries, for use with domestic satellite telephone communications systems. The system is composed of a parabolic receiving antenna, a preamplifier, a converter and a multiplexer. Originally, a remote van would receive the satellite signal, process, and convert the signal for longline distribution to subscribers. However, a more practical system concept for solar power applications would consist of a receiving station which retransmits the signal to a central station for processing and distribution. The reason for this change is that direct conversion for longline distribution requires that the station supply signalling voltage and operating power for each subscriber. This would place too high a power requirement on the solar array.

2.0 SYSTEM REQUIREMENTS

Solar panels for the system can be mounted on the same mast or tower as the microwave antenna in smaller systems and on the van roof top for larger systems. In general, one multiplex channel is required for every three subscribers. Thus, a 300-channel system can supply approximately 1000 subscribers. The solar array costs \$4975 and generates about 40 amps. The system pre-amp costs about \$2000 and draws just under 1.5 amps. The pre-amp output drives a converter which incorporates thin film circuits and costs approximately \$15,000.

The drain is about 2.7 amps. The multiplex unit costs \$12,000 and draws 5.4 amps. The shelter to house this equipment is typically 8 x 10 x 12 feet (2.4m x 3m x 3.6m), fiberglass construction, mounted on skids and includes a lift hook for transport by crane. The cost of the shelter is approximately \$4,000.

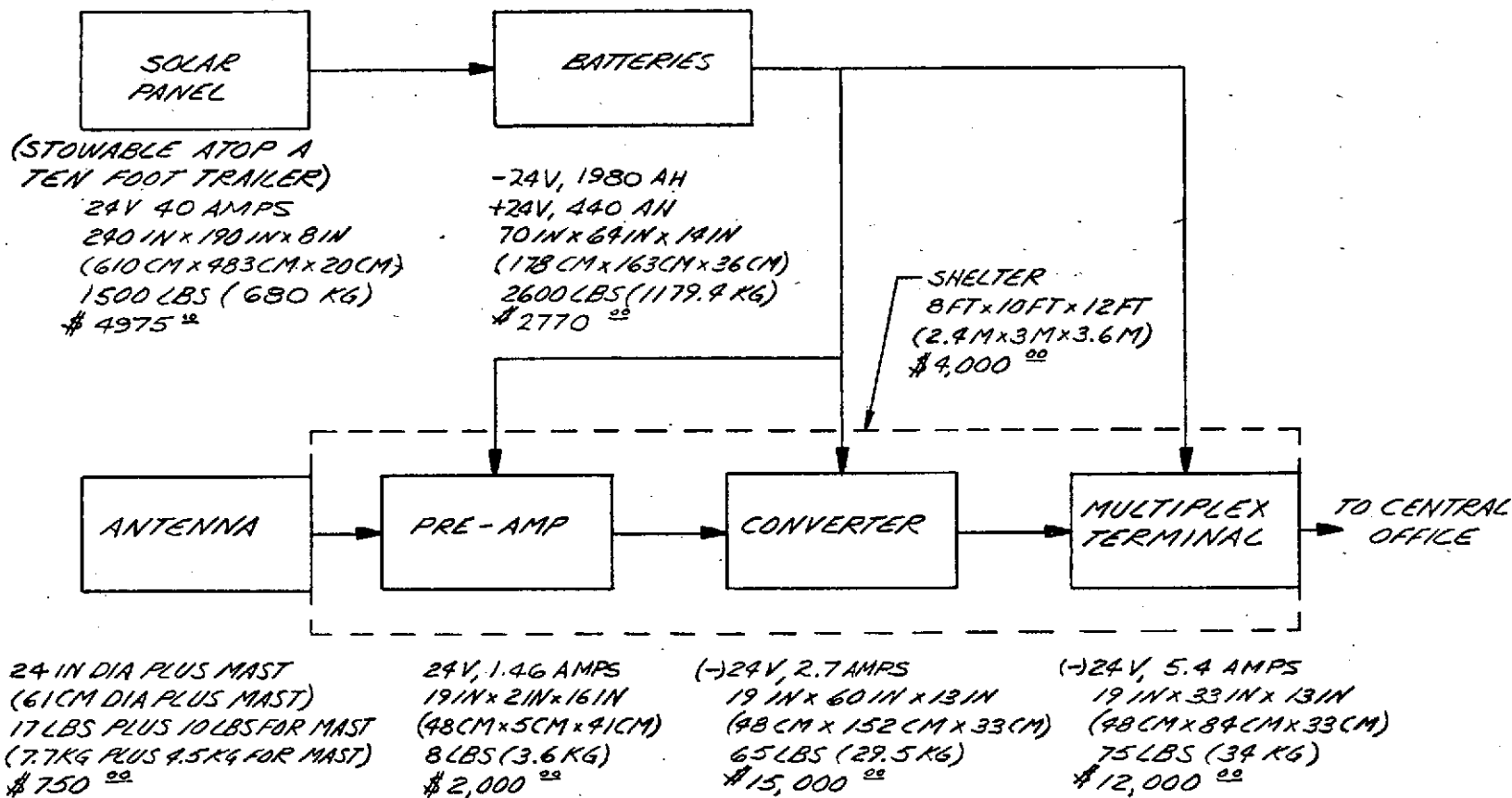
3.0 ADVANTAGES AND DISADVANTAGES

Advantages of the solar power systems for telephone communications are:

1. System can operate for long periods of time unattended.
2. Offers economy of operation over thermoelectric generator or motor generator power sources.
3. Provides a substantial weight savings over other power sources.
4. Brings effective communications to remote regions which cannot now be reached by ground systems.
5. System can also be used for education, news, health service, weather, agricultural information broadcasts, and data transmission.

The prime disadvantage to the system, other than the relatively high initial costs, is the fact that in the U.S., there are only two major telephone companies which must accept and use the solar power concept. Foreign governments are, however, prime candidates, especially those using or planning satellite communications.

CONSISTS OF ONE 1KW ARRAY
 21 AMPS @ +24V
 13 AMPS @ -24V



SOLAR POWER SUPPLY FOR
 REMOTE TELEPHONE COMMUNICATIONS
 CODE 5C

Power for TV Receivers in Remote Areas for Reception
of Education Programs Via Satellite
(Code 7 C)

1.0 DESCRIPTION OF THE SYSTEM

The system consists of a solar power supply and batteries designed to provide power for the preamplifier, demodulator, and TV receiver. Known as the Health/Education Technology (HET) Experiment, the program will use the NASA ATSF satellite. Responsible agencies are the Department of Health, Education and Welfare and the Federation of Rocky Mountain States. A contract for 100 of these ground stations was awarded to the Westinghouse Electric Corporation in Baltimore. Approximately 68 of these units will be used in the Rocky Mountain states, with the balance split between Alaska and Appalachia. The Canadian government has also expressed interest in the system. The contract is being administered for Westinghouse by Baltimore Defense Electronics.

2.0 SYSTEM REQUIREMENTS

Solar panels for the system can be mounted on the receiving antenna mast, or separately. Again, as in most applications, the high first cost of the solar panel makes it appear to be an unattractive alternative power source. If we annualize the cost and compare it against a conventional motor generator, the solar power system compares favorably. The programming will average 4.5 hours per day, 5 days per week. The solar panel required to power this system with a black and white TV receiver will have to generate 4.3 amps and will cost approximately \$495. The black and white TV receiver will pull about 1.7 amps and will cost approximately \$100. If a color receiver is used (specifically a Sony Trinitron) the requirements of the panel will increase to 4.8 amps at a cost of about \$570. The Sony Trinitron, recommended due to its low power drain, retails for \$400. It should be noted that a study conducted by Stanford University revealed that color TV provides only about 5% improvement in learning factors compared with black and white. Therefore, we are recommending a black and white TV receiver. The system also includes an 8-foot antenna dish that draws about 40 ma and costs \$900. A Hewlett-Packard converter-receiver

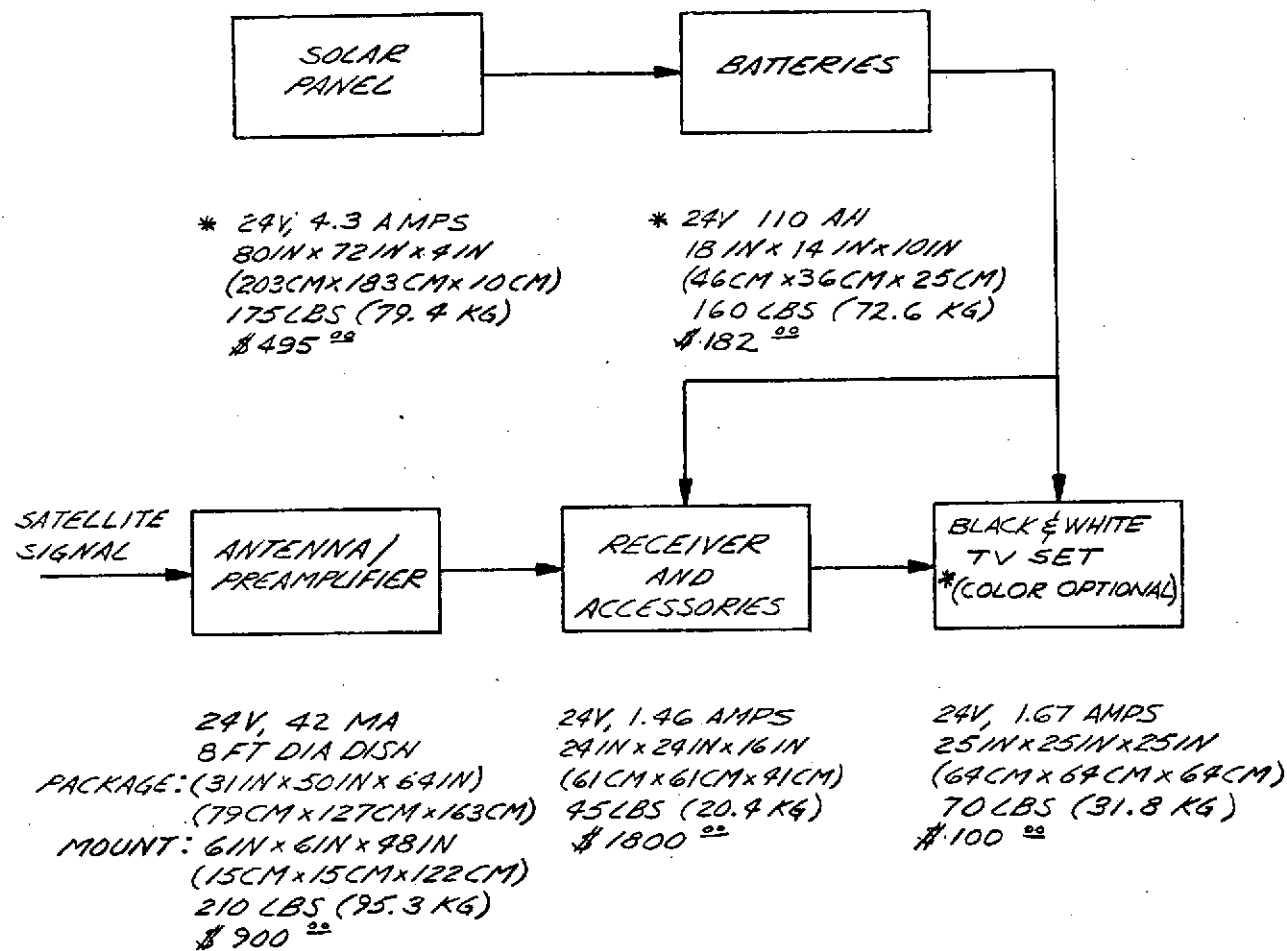
combination is the other link in the system. It draws 1.5 amps and costs approximately \$1800.

3.0 ADVANTAGES AND DISADVANTAGES

The advantages of the solar powered educational TV system are as follows:

1. Economic advantage in areas where commercial power is not presently available.
2. Increases flexibility of use of the basic HET experimental equipment in that the equipment is portable and can be readily moved.
3. Reduced maintenance and fuel costs compared with other power sources (except commercial power).
4. Quiet power generation.

The primary disadvantage of the system is the relatively high initial cost for the solar array. Present plans for foreign governments call for relatively inexpensive systems.



*WITH COLOR TV:

COLOR SET, 2.1 AMPS, \$400⁰⁰
SOLAR PANEL, 4.8 AMPS, \$570⁰⁰
BATTERIES 220AH, \$364⁰⁰

SOLAR POWER SUPPLY FOR TELEVISION
RECEIVERS FOR RECEPTION OF EDUCATIONAL
PROGRAMS VIA SATELLITE (CODE 7C)

Standard Low Power Portable Module
for Forestry Communication Systems
(Code 6 G)

1.0 DESCRIPTION OF THE SYSTEM

The system consists of a number of small solar panels which are physically joined by means of separable hinges for ease of carrying or transporting. Quick disconnect electrical connections are provided which allow the panels to be electrically combined in a variety of series-parallel combinations to provide the required output voltage and power to any communication system configuration. At 80 pounds, the entire system is transportable into the field to provide emergency communication capability. A ranger could direct aircraft drops on forest fire hot spots, direct search and rescue operations for lost campers, etc. The system provides adequate power for a one minute message every ten minutes during an eleven hour time segment. In addition, the capability to communicate for 15 minutes during a one hour time segment is available.

2.0 SYSTEM REQUIREMENTS

Each solar panel in the module would be approximately 18 inches high by 16 inches wide. Four of these panels would be required to operate the communication system. The case should be constructed of lightweight materials and a suitcase-type handle and latching mechanism provided for transporting the module. Accessory brackets should be provided to allow mounting on flat surfaces as well as independent supports. Each detachable panel weighs approximately 20 pounds, generates 2 amps, and costs \$60. The communications equipment draws about 2.9 amps, weighs 50 pounds, and costs \$1225.

3.0 ADVANTAGES AND DISADVANTAGES

The advantages of the standard low power portable module for forestry communication systems are:

1. Can be used to provide communications during daylight hours, for a multiplicity of purposes and in any location.
2. Modular design provides high degree of flexibility in voltage and power output for a variety of communication system configurations.

Possible disadvantages include problems with transportation and the difficulty of reliable electrical interconnects. Also, the lightweight portable feature presents difficulties in securing the unit against wind.

SOLAR PANELS MAY BE
CONNECTED IN VARIOUS
SERIES/PARALLEL
COMBINATIONS: 6V-8A,
12V-4A, 24V-2A

SOLAR PANEL
MODULE
(4 REQ)

BATTERY
PACK

COMMUNICATIONS
BASE STATION

30 WATTS
OUTPUT

EACH { 6V, 2AMPS
PANEL { 18IN x 16IN x 2IN
(46CM x 41CM x 5CM)
TOTAL WT 20LBS (9KG)
\$240⁰⁰

24V, 30 AH
15IN x 15IN x 7 IN
(38CM x 38CM x 18 CM)
48 LBS (22 KG)
\$127⁰⁰

24V, 2.92 AMPS
38IN x 22IN x 12IN
(96CM x 56CM x 30CM)
51 LBS (23KG)
\$1225⁰⁰

STANDARD LOW POWER PORTABLE MODULE
FOR FORESTRY COMMUNICATION SYSTEMS
(CODE 6G)

Power Supply for Solid State Anemometer
(Code 6 MI)

1.0 DESCRIPTION OF SYSTEM

The system consists of a solid state anemometer to supply data to a recorder and for a transmitter. A solar cell array will supply power to a storage battery for powering the complete unit. The system can be used for measuring wind speed and direction in wind tunnels and ducts and also fluctuations in air currents indoors and out.

2.0 SYSTEM REQUIREMENTS

The solar panel required to power the solid state anemometer generates 4.2 amps at 24 volts, at a cost of \$495. The anemometer draws 50 ma and costs approximately \$700. The strip-chart recorder draws 100 ma at 1.5 volts and costs about \$1500. The transmitter draws 600 ma at 24 volts and costs \$600. The calibrate mode of most of these instruments requires approximately 50 ma additional current if certain warning lamps are disabled. This practice is acceptable in critical power applications. Otherwise, the lamp requires an additional 40 ma at +12 V.

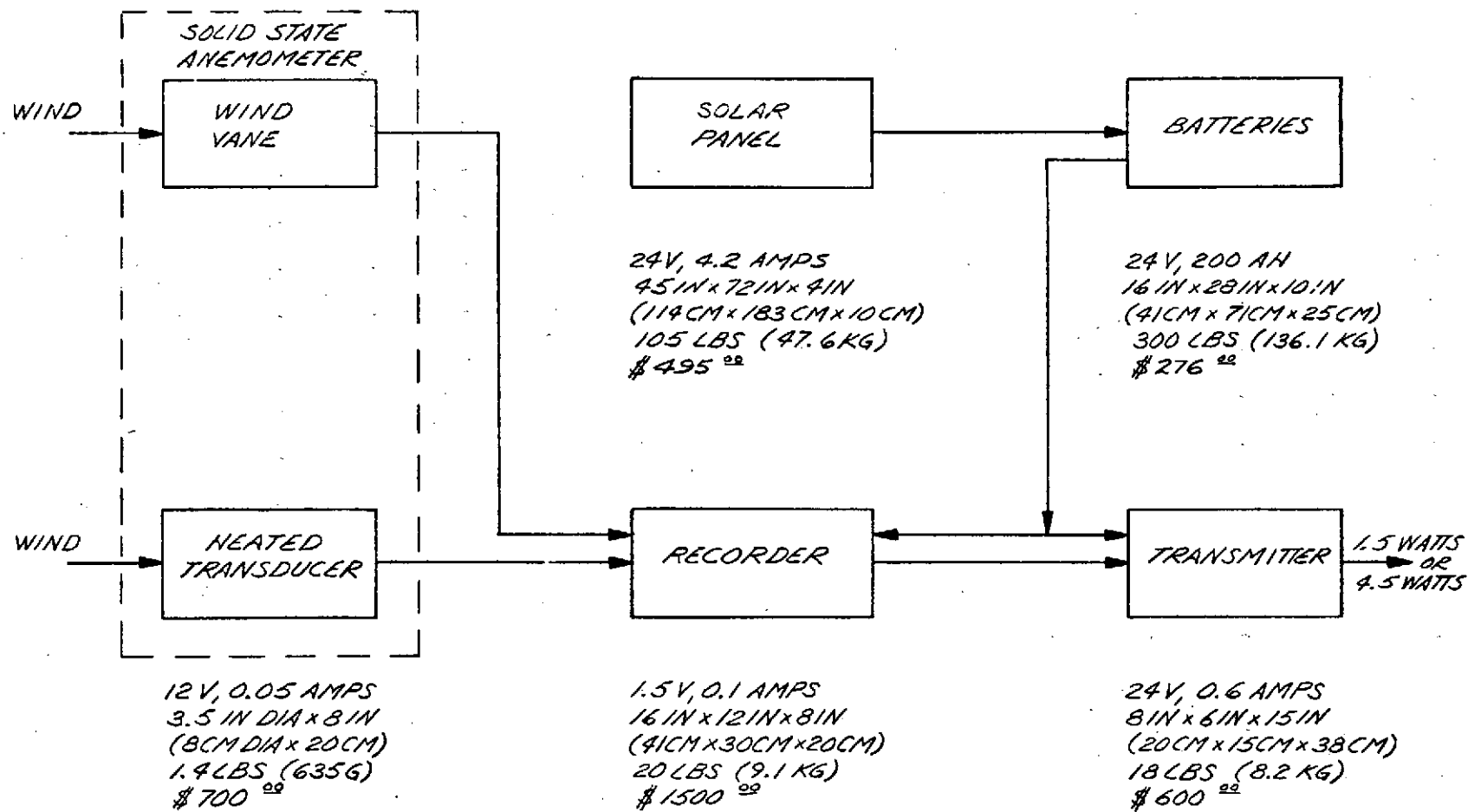
3.0 ADVANTAGES AND DISADVANTAGES

The advantages of the solar powered anemometer are as follows:

1. Even with mechanical vanes and blades, reliability of the system is good (1,000 million revolutions - 3 to 4 years normal operation).
2. The amount of power required for a solid state device is small, and the elimination of mechanical movement and the possibility of fouling is greatly reduced.

3. The solar array can also measure other parameters such as incident solar irradiation, etc.

The primary disadvantages are the somewhat restricted market size which, in turn, results in a higher unit cost.



SOLAR POWER SUPPLY FOR
 ANEMOMETER SYSTEM
 (CODE 6 MI)

Power Supply for Instrumentation Used to Monitor
Noise Pollution
(Code 6 EP)

1.0 DESCRIPTION OF THE SYSTEM

The system consists of a small solar panel attached to a sensing device which measures noise levels in both urban and remote areas. In urban applications, the device will monitor aircraft, automobile engines, train and road noise levels, factory and construction sound levels. In rural areas, a major emphasis on noise pollution control has resulted from the increased use of off-road recreational vehicles (ORVV's). The type of system used depends on the type of sounds to be monitored. For applications such as monitoring aircraft approaches (specifically Los Angeles International Airport), the sensing unit is mounted on a pole with spikes attached on the top of the unit to deter birds from landing. The pickup microphone extends well above the recording unit to minimize sound reflections. The solar array, for the same reason, should be mounted well away from the recording equipment, preferably below. For applications such as monitoring off-road recreational vehicles in remote areas, the sensing equipment will probably be used in conjunction with a recording device to facilitate later detailed analysis. It should be noted that tape recording equipment, required to effectively measure and analyze sound levels, range in price from \$5000 to \$8000 per unit. The cost of placing such units in remote locations could be prohibitive and would probably be feasible only in highly sophisticated installations. A typical remote installation would more probably incorporate a low cost chart-pen recorder.

2.0 SYSTEM REQUIREMENTS

Solar panels and their associated mounts must be able to withstand severe wind loads and icing conditions. The solar panel will generate approximately 300 ma and sell for \$25. In this application, the power supply is not a major contributor to the cost of the entire system. The microphone and amplifier will draw about 100 ma and cost \$5000. The filters demand 400 ma at 4.5 volts,

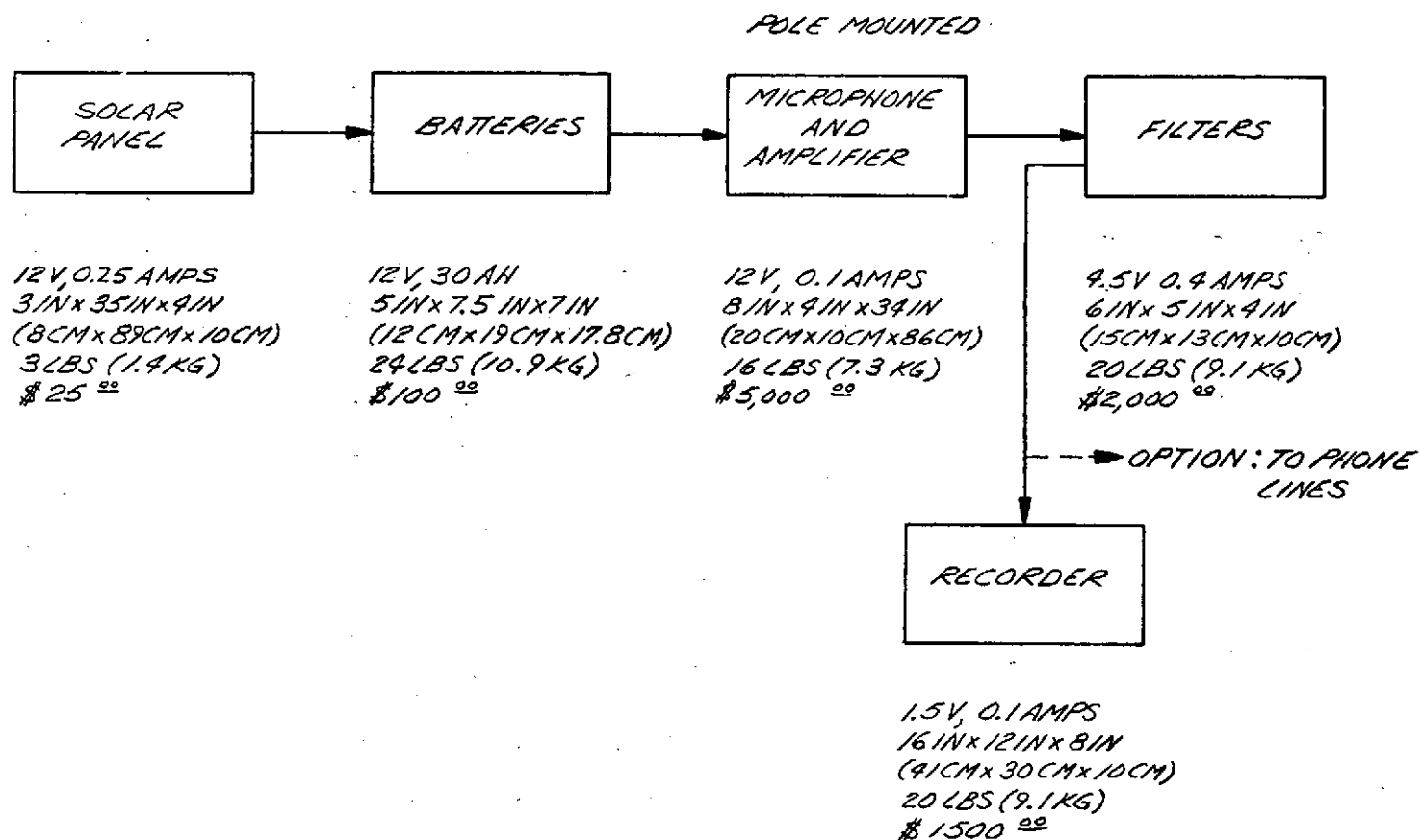
costing about \$2000. The chart recorder, prevalent in approximately 75% of the potential application, draws 100 ma at 1.5 volts and costs about \$1500. In some urban installation, a modest amount of system vibration can be expected from elevated trains, etc.

3.0 ADVANTAGES AND DISADVANTAGES

The advantages of the solar powered monitor are as follows:

1. Ease of installation in both urban and rural applications. Many units would be mounted on building roof tops which do not have commercial power readily available.
2. The use of noise level monitors is expected to increase at a substantial rate.
3. New units are at the design stage where the choice of a power source has not been firmly established.

The primary disadvantage is that many of the systems utilize chart recorders which, in turn, require periodic maintenance.



SOLAR POWERED NOISE
 POLLUTION MONITOR (CODE 6EP)

Solar Power Supply for Remote Perimeter
Protection Devices
(Code 1 S)

1.0 DESCRIPTION OF THE SYSTEM

This system consists of a group of seismic detectors, called geophones, buried in the ground at intervals dependent on the type of terrain to be monitored, and powered by a battery which is recharged by a solar array. The purpose of the system is to detect the movement of vehicles or personnel within the secured area, and to transmit an alarm signal to a central station whenever such movements occur. The processor, which is also buried in the ground, is used to screen out unwanted types of signals. Among the unwanted signals are seismic disturbances, certain types of animals, winds which produce motion in trees, etc. A second group of sensors for audio detection can also be incorporated, thereby increasing the capability and reliability of the system. From a system operational viewpoint, it is important that the internal batteries require replacement no more often than is absolutely necessary.

2.0 SYSTEM REQUIREMENTS

The replacement of batteries and system maintenance must be kept to a minimum in order to avoid disclosure of the exact location of the sensors. The solar array must be camouflaged in such a way as to be relatively undetectable from a distance of 50 yards or more. The solar array required for this application will generate approximately 500 ma and cost \$45. The geophones are passive devices costing approximately \$35 each. Up to five (5) geophones can be used on a system. Two basic types of processors are available. One is a digital system used to detect footsteps, and the other is an analog system designed to detect either footsteps or vehicles. The former is twice as expensive due to the fact that, as a footstep detector, it is more sensitive and requires more complex circuitry for differentiation between the different types of terrain vibration which could activate the geophones. The less sensitive

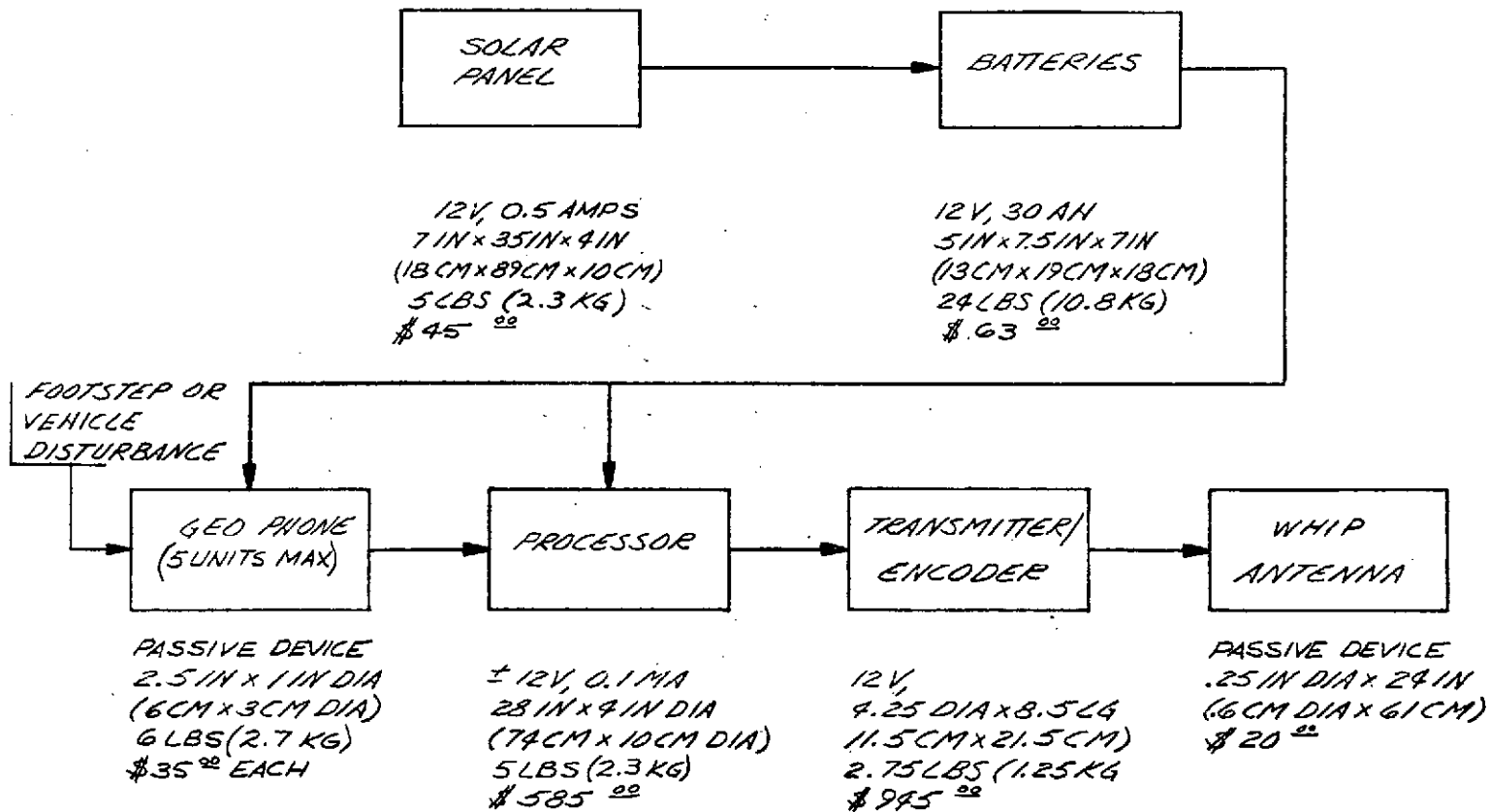
device, which we recommend using, draws 100 ma and costs \$585. The transmitter demands only 5 ma and costs \$945. The whip antenna, like the geophones, is a passive device. The cost of the antenna is approximately \$20.

3.0 ADVANTAGES AND DISADVANTAGES

The advantages of the solar powered perimeter detection device are as follows:

1. Provides reliable power for long periods of time.
2. Allows installation of equipment in areas previously not suitable for such systems.

The major disadvantage is the need for camouflaging the solar array without substantially increasing the cost of the installations. Widespread use of solar cells in this application depends upon numerous installations and corresponding reasonable costs.



SOLAR POWERED REMOTE PERIMETER PROTECTION SYSTEM (CODE 1'S)

Solar Water Pump System
(Code 1 IC)

1.0 DESCRIPTION OF THE SYSTEM

The system consists of an electric motor operating in conjunction with a solar power supply to drive a water pump for use in remote areas and underdeveloped countries. A purifier and water holding tank are also included. This system is designed to provide non-brackish water for personal consumption (drinking, cooking, etc.) and watering livestock, as well as pump water for irrigation on small farms. The ultraviolet radiation method of water purification was selected over chlorination for two (2) reasons. First, it has a lower power requirement. Second, the ultraviolet system is very reliable and has a distinct advantage over chlorination in underdeveloped countries, since chlorine does not kill certain viruses, such as the polio virus. The system also contains all connecting pipe and holding tanks. This pumping system is designed to operate where the water table is relatively high. For example, many locations in India have water levels of only 20 feet. The pump would provide a modest flow into a nearby tank with a modest run of connecting pipe. Where the mineral content of the water is relatively low, operation of over ten years can be expected.

2.0 SYSTEM REQUIREMENTS

The water pump should be designed to provide an average flow of approximately 10 gallons per minute from an average depth of 20 feet below the surface. This requires a head of approximately 36 feet which includes pipe, motor shaft and pump impeller losses. The pump would operate at about 1,700 RPM requires approximately .03 horsepower per impeller stage. Six stages would be required, therefore requiring .18 horsepower. The type of pump required would most likely be a "close coupled 6 stage 4R" type with an efficiency ratio of 1.15. The solar panel will have to generate 2.1 amps at 90 volts for the water pump and motor and purifier. As well, it must generate 3 amps at 12 volts for the controller. The cost of the solar panel is \$995. The level sensor is a passive device and costs \$24. The controller operates at 12 volts and draws 3 amps. It costs \$45. The water pump and motor demands 1.7 amps at 90 volts and cost \$95.

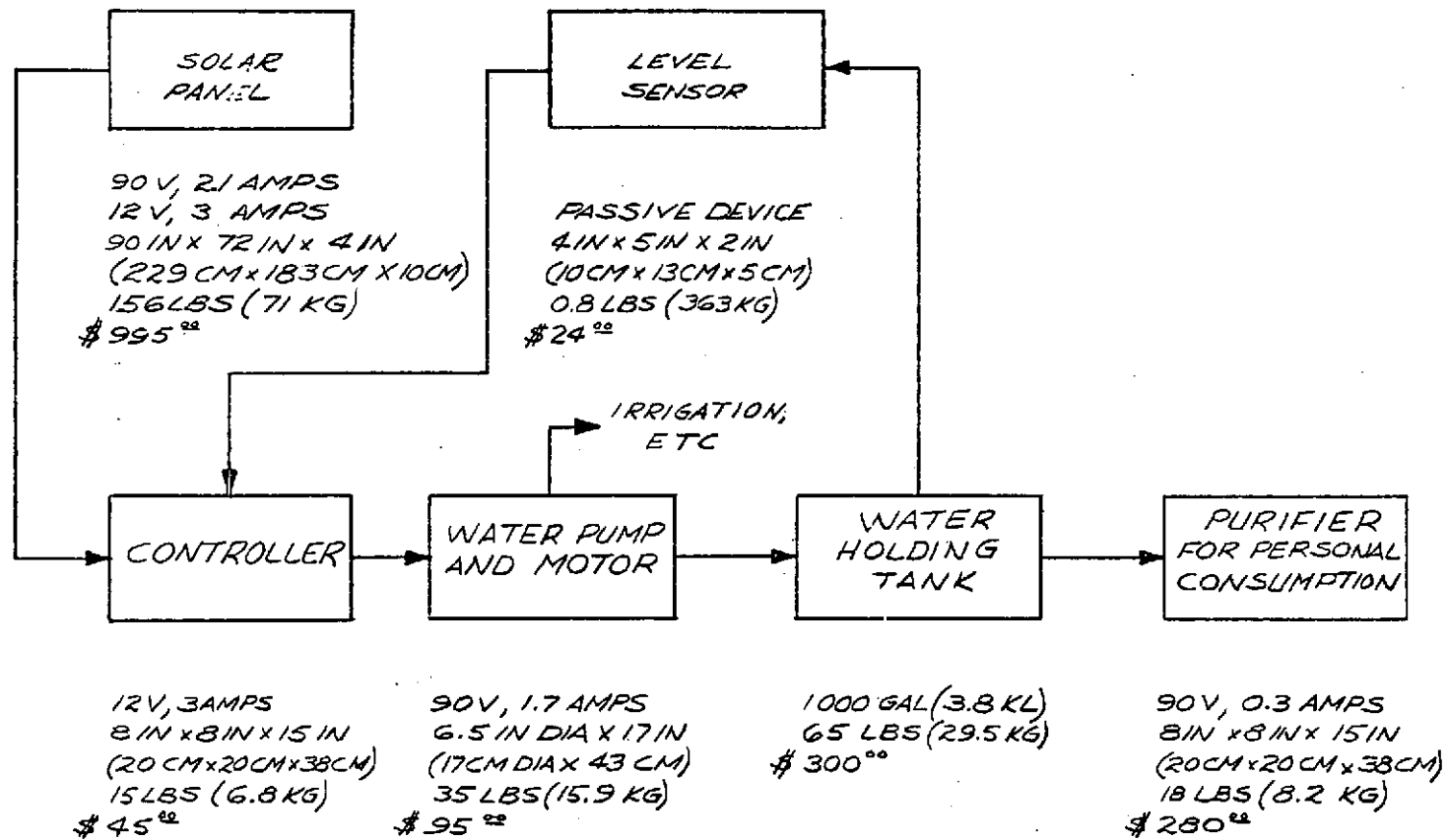
In the Middle East, the average remote village contains between 100 and 200 persons. Assuming an average consumption of 1 gallon of water per person per day, the requirement for purified water is between 100 and 200 gallons per day. The water holding tank is a flexible vinyl plastic liner dropped in an elevated reservoir. It has a capacity of 1000 gallons (5 to 10 days supply) and costs \$300. The ultraviolet purifier operates at 90 volts and draws approximately 300 ma.

3.0 ADVANTAGES AND DISADVANTAGES

Advantages of the solar water pump system are:

1. The system costs nothing to operate; the initial cost is the only cost.
2. Design is simple and foolproof; requires no special training for its installation and operation.
3. The system can be expected to operate reliably for years, without attention.

A major disadvantage is the relatively high cost of the system. As well, the heavy weight makes portability a problem.



SOLAR POWERED WATER
 PUMPING SYSTEM
 CODE 1 IC

5.0 FINAL EVALUATION

5.1 General

The Final Evaluation under the NASA contract called for further detailed analysis of the selected applications, and subsequent reduction of the list from ten applications to two. Careful analysis revealed several applications that were worthy of consideration for the Detailed Design effort.

Three applications were subsequently submitted for review by NASA, with the recommendation that certain factors relating to overall NASA objectives be considered in the final screening and evaluation process. In particular, the desirability of interfacing with existing domestic government programs, and the advisability of sponsoring projects with foreign governments, are both important factors. To provide NASA with the widest possibility of options, the three recommended applications, in our opinion, represented the best balance between technical and economic feasibility, user acceptance, and fulfillment of the program objective of overall social benefits.

The three selected applications are:

1. Solar power supply for TV receivers in remote areas for reception of educational programs via satellite (Code 7C)
2. Solar water pump system (Code 1 IC)
3. Barrier flashers and warning lights for traffic control (Code 2 T)

Application (1) represents a use of solar power to provide educational social benefits for domestic use and in underdeveloped countries with the most probable usage being the latter. Application (2) is unique in that the pumping and subsequent storing of water in a holding tank circumvents the necessity of a battery - an advantage not possessed by any other of the many applications studied during this program. Application (3) is an urban usage of solar cells with a direct social benefit of improving highway and construction safety, including the saving of lives. The cost of a solar power flasher is the prime factor which will measure the success of the product.

These applications are discussed in the following paragraphs, including the general background data which led to their selection.

5.2 Solar Powered Receivers for Educational TV Programs

This application was selected because of its social benefits and suitability for use with solar power. In review, the Health-Education Telecommunications (HET) experiment, jointly sponsored by NASA, the Department of Health, Education, and Welfare, and the Corporation for Public Broadcasting, will involve health and educational experiments in Alaska, Appalachia, and the Rockies. The satellite will be used to distribute health and educational materials to public-broadcast stations, cable-TV headends, translators, and community centers. The educational experiments planned for the Rockies are the responsibility of the Federation of Rocky Mountain States, Inc., a non-profit corporation dedicated to improving the scope and quality of economic, social, educational, and cultural opportunities in the Rocky Mountain region. The Broadcast and Engineering Component of the Federation has been designated to serve as Operations Manager of the HET ground network. Working closely with NASA's Goddard Space Flight Center, the Federation has engineered the network of ground stations that will be used in the HET experiment. The basic objective of the HET experiment is to gather data on the use of an educational telecommunications satellite and the associated human support system. This information can be used to guide decisions regarding the investments of funds and other resources for future efforts.

Interestingly enough, little concern was given to the power supply system since the initial phases of the program were domestic experiments and it was assumed that commercial power was readily available. In actuality, foreign applications will require auxiliary power. The fact that solar power could replace noisy motor generators is a plus factor, especially for classroom activities.

A second consideration which makes solar power practical for this application is the selection of a television receiver. A color receiver has been favored by many involved in the system design. However, a TV receiver has not been included in the HET experiment since, again, it was assumed that each site would already have a receiver. The optimum selection of a receiver for use with a solar powered

system would be a black and white solid state receiver as opposed to color. The black and white set uses less power. Tube type black and white sets are less expensive at present, but their cost will be comparable to solid state sets within five years. Color has a negligible effect on the learning process (less than 5%) according to a recent Stanford University study. The cost advantage, particularly in developing countries, could force the decision to black and white.

Reasons for selecting this applications are summarized as follows:

1. Solar supplies can be readily integrated into a program which has significant social benefits.
2. The operation of solar power supplies around classrooms of students in remote locations has advantages in that the operation is silent compared to motor generators and dangerous fuel is not required.
3. The use of solar energy as the primary power source will have unmeasurable educational value in demonstrating the capability and promoting the use of solar power to the students.....customers of tomorrow.
4. The operating duty cycle of the system as detailed by the programming material is such that the cost of the solar array is reasonable.
5. The potential market for the arrays, particularly in developing countries, is substantial.
6. Will generate production of approximately 2.4 million solar cells over the next five (5) years.

5.3 Solar Water Pump System

A solar water pump system has direct agricultural applications in pumping water from wells and draining flooded farmlands. Many variables come in to play in the design of such a system, such as the amount of water required, size of the holding tank, performance characteristics of the pump, depth of the wells, solar radiation characteristics, etc. All of these variables interrelate in the development of a solar water pump system which will have wide-spread application. Unfortunately, many of these factors are difficult to assess on a theoretical basis.

In order to obtain useful data, a system that could be functional from a practical sense in the field would be most valuable. A system designed for rather high water tables can most effectively serve this purpose. Permitting the use of such a system on an experimental loan basis to a developing country would provide important data while demonstrating the social benefit of such a system to the country. The need for a shallow pumping system in India, for example, is very real. The following paragraphs provide an overview of the situation in India which clearly establishes the potential of the proposed solar application.

India is endowed with abundant sunlight, adequate water resource potential and good soils, all requisites for successful agriculture. Yet, the average yields of all crops are the lowest in the world. Agriculture in India is predominantly dependent on the monsoon. Out of 376 million acres sown, only 18% is irrigated. Frequent droughts and floods are common. Although major irrigation projects have come a long way in controlling floods and extending the area under irrigation, recent droughts have for two consecutive years caused enormous amounts of human suffering.

The topography and the soil characteristics of the Indo-Gangetic Plain are highly favorable to the formation of underground water reservoirs formed by interconnected sand-bed aquifers. The vast underground reservoir is an important source of water for supplementing the existing water supply and also to promote intensive agriculture.

The underground water potential is excellent, but it cannot be tapped without adequate energy for pumping. By supplying power to lift the underground water, the production of food crops can be raised substantially. Present devices used for lifting water range from the simplest primitive methods like swinging buckets, to the persian wheel, chain pumps, electric or diesel pumping sets and tubewells. Even for well irrigation, the availability of sufficient power for lifting water is a limiting factor because the farmer mostly has to depend on bullock power which has numerous limitations. Estimates indicate that if irrigation waters were available in adequate amounts, the crop yields would improve 3 to 4 times overall. Wheat production, in particular, would increase 8 to 9 times.

In some of the areas, however, the rise of the water table has led to the menace of salinity and alkali. Drainage is badly needed to improve this situation. Again, a solar power system could provide adequate energy to drain the saline water off.

Reasons for selecting the solar water pump application can be summarized as follows:

1. The storage of water in a holding tank is a unique advantage since the battery necessary in most applications studied is not required.
2. The feasibility of the system can be proven by developing a prototype model at reasonable cost using a modest solar array.
3. Field tests can be performed in a developing country to obtain operational data.
4. Social benefits are realized since the system fills a definite need.
5. The system's capacity can be expanded for domestic use once feasibility is demonstrated.

6. Will generate production of approximately 1 million solar cells over the next five (5) years.

5.4 Barrier Flashers and Warning Lights

A barrier flasher incorporating a small solar array is completely feasible and can compete with conventional flashers if properly positioned in the marketplace.

Additional research has uncovered a number of factors which favor the selection of this application. These factors are:

1. The market is continuing to increase and is expected to reach 1.5 million units by the end of 1973.
2. There is willingness by several manufacturers to assist in the development and promotion of a high intensity warning flasher.
3. The theft rate of flashers is declining - a recent test in the Harlem section of New York showed a reduction from 35% theft and vandal rate to 12% by incorporating improved anti-theft measures. This is a positive factor in that the higher initial cost of the solar powered flasher can be more readily justified.

Approximately 75% of all flashers are presently handled through rental and leasing organizations. These organizations are very cost conscious and are quite happy to continue handling conventional flashers. Their interest in new innovative products is not great. However, a high intensity flasher directed toward 5% of the market and sold directly to municipalities has a good probability of success. Following initial acceptance of the solar powered flasher, the market share should increase as government standards are written around the products.

In summary, criteria used for selection of this application were:

1. Large market size.
2. An urban usage as opposed to other applications which are primarily used in remote locations.
3. Will generate production of approximately 5 million solar cells over the next five (5) years.

6.0 DETAILED DESIGN

6.1 General

The Detailed Design Effort called for the generation of detailed drawings of the two applications selected as a result of the Final Evaluation. The key underlying consideration prevalent throughout the Detailed Design Effort was to develop a quality system that, based on market analysis, would sell at a competitive price. To achieve the desired results, these procedures were followed:

1. Wherever possible, standard, available components were used. This minimizes costs of retooling.
2. Any changes or additions to existing hardware were made as economically as possible in an attempt to maintain a competitive price.

To meet the above criteria, the following steps were taken:

1. All of the available data was reduced to identify the essential components.
2. Alternatives were evaluated and trade-offs made to make sure the criteria was met with a minimum of expenditure and change.
3. Once the design was established, cost vs. value options were evaluated.
4. Human Engineering was a consideration factor in the final product design.

The detailed drawings that follow in this section are prefaced by a narrative

that includes:

1. Description of the system.
2. Design and Marketing Considerations.
3. Costs.
4. Conclusions and Recommendations.

Barrier Flashers, Warning Lights
for Traffic Control
(Code 2 T)

1.0 DESCRIPTION OF THE SYSTEM

The system consists of a solar array encapsulated into the top of the flasher light, mounted to the surface of a portable or transportable warning barrier, plus a rechargeable battery. Present barrier flashers do not meet the illumination requirements under the existing ITE (Institute of Traffic Engineers) Standards, approved May 19, 1971 and adopted by the Federal Government and most states. Even so, no provisions were ever established to enforce the new standards. The flasher manufacturers have been up-at-arms with the government, arguing that the light specifications can not be economically met. This negotiation has been in progress for the past two years. The manufacturers will be presenting their final case at the National Safety Congress meeting in Chicago, October 29 - 31, 1973. It is anticipated that the new federal and state standards developed from the negotiation will be less stringent than the existing ones. Since the illumination and lifetime requirements are in such a state of flux, the following assumptions were made, thus dictating the characteristics of the solar powered barrier flasher unit:

1. A flashbulb intensity of .5 candelas. This is twice the illumination of present barrier flasher units.
2. A lifetime characteristic of 3000 hours.

2.0 MARKETING CONSIDERATIONS

Several assumptions were confirmed as a result of the detailed design effort. A brief discussion of each along with general points of interest are contained in this section.

1. The solar powered barrier flasher system will supply sufficient power to fully recharge the flasher battery during daylight hours. This will extend the battery life equal to the life of the flasher unit. As well, the bulb being used will also survive the flasher unit. Hence, battery and bulb replacement costs and maintenance costs for barrier flashers will be considerably reduced.
2. We have generated considerable interest in the solar powered flasher unit with Paralta, the largest manufacturer of flasher units. As such, they have been very co-operative in providing information and have given strong indications of wanting to work closely with us in developing the unit.
3. Ray-O-Vac, a prime supplier of the primary batteries for existing flasher units, has undertaken a major marketing campaign to introduce rechargeable batteries to the barrier flasher market. They are advocating a direct savings with rechargeable batteries over primary cells on maintenance cost alone. This strengthens the marketing position in that solar cells will keep the batteries charged instead of continuous removal, recharge and replacement.

3.0 DESIGN CONSIDERATIONS

Following is a brief discussion of the design alternatives considered with reasons for selection.

1. Various packaging alternatives were developed and evaluated. The existing packaging was selected for the following reasons:
 - (a) New tooling for lens would cost in excess of \$70,000.

(b) Minimal changes in the product are required to adapt solar power and meet the new ITE standards.

(c) It was possible to design the electronic circuitry and charging rate to accommodate the new bulb and rechargeable battery.

(d) The alterations include:

(1) The addition of the solar array.

(2) The addition of plastic retainers and brackets for the array.

2. Other considerations include:

(a) Present leakage problems would be overcome in that the solar array shields the rest of the flasher unit, providing added protection (like an umbrella).

(b) The side of the solar cell retainer provides additional space for a reflectorized tape, a logo, a direction arrow, advertising, etc.

(c) The unit maintains the same characteristics from the standpoint of durability, vandalism, etc.

(d) The acrylic cover on top of the solar cells presently has a flat design. Instead of being flat, where light is wasted, we can mold the cover to direct the wasted light onto the cells.

4.0

COSTS

1. Tooling Costs

2 cavity molds for solar cell cover	-	\$7,000
1 cavity mold for solar cell retainer	-	\$4,500
Modification to lens mold	-	<u>\$2,000</u>
Total Tooling Cost	-	\$13,500

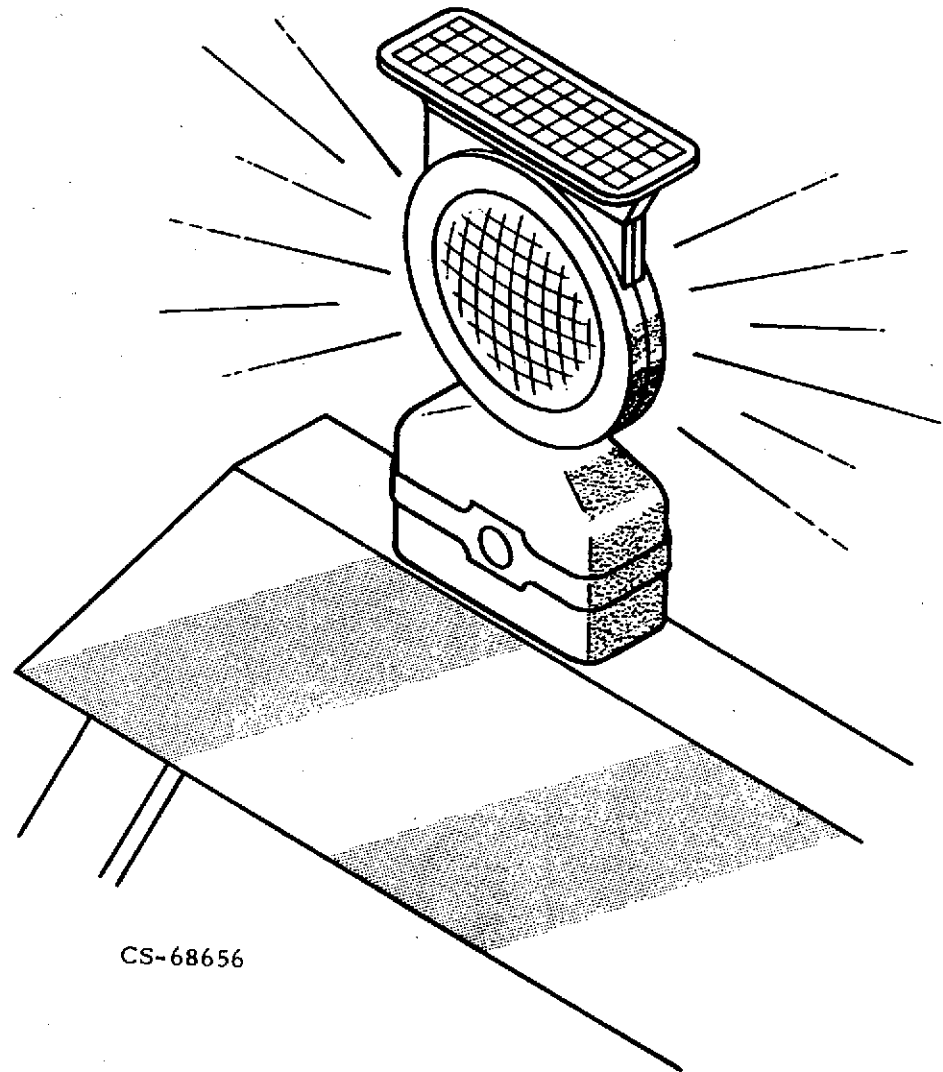
2. Parts Costs (100 Units)

Paralta light	\$20.00
Rechargeable Batteries	\$10.50
Solar Conversion Kit	<u>\$26.00</u>
including solar cells, encapsulation, diode, wiring, miscellaneous parts, RTV for potting, etc., labor and G and A	
Barrier Flasher Cost	\$56.50

CONCLUSIONS AND RECOMMENDATIONS

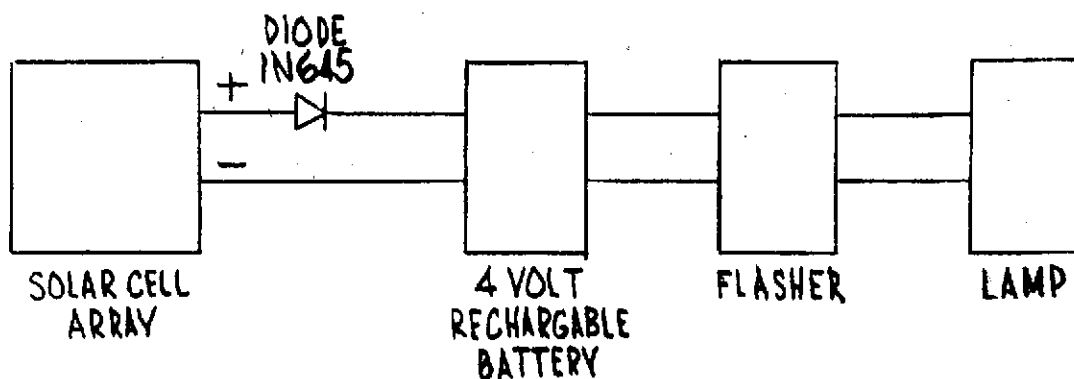
1. The detailed design proved the practicality of the solar powered barrier flasher unit both from a capability and low cost standpoint.
2. Several prototype models should be built to prove out the design.
3. Once the mechanical and electrical aspects have been proven, the aesthetics of the product should be addressed.

BARRIER FLASHER



CS-68656

PREPARED BY: LANGAN	spectrolab A Division of Watson Inc.	PAGE NO. OF
CHECKED BY:		Job No.
DATE: 9-26-73	TITLE BARRIER LIGHT SCHEMATIC	REPORT NO.
		MODEL NO.



LAMP : G.E. #45 35A, 3.2V., .5CP, 3000 HR. RATED LIFE

LOAD = LAMP + SURGE + FLASHER x DUTY CYCLE x HOURS/DAY

$$.42 \times .1 \times 14 \text{ HRS/DAY} = .588 \text{ AH/DAY}$$

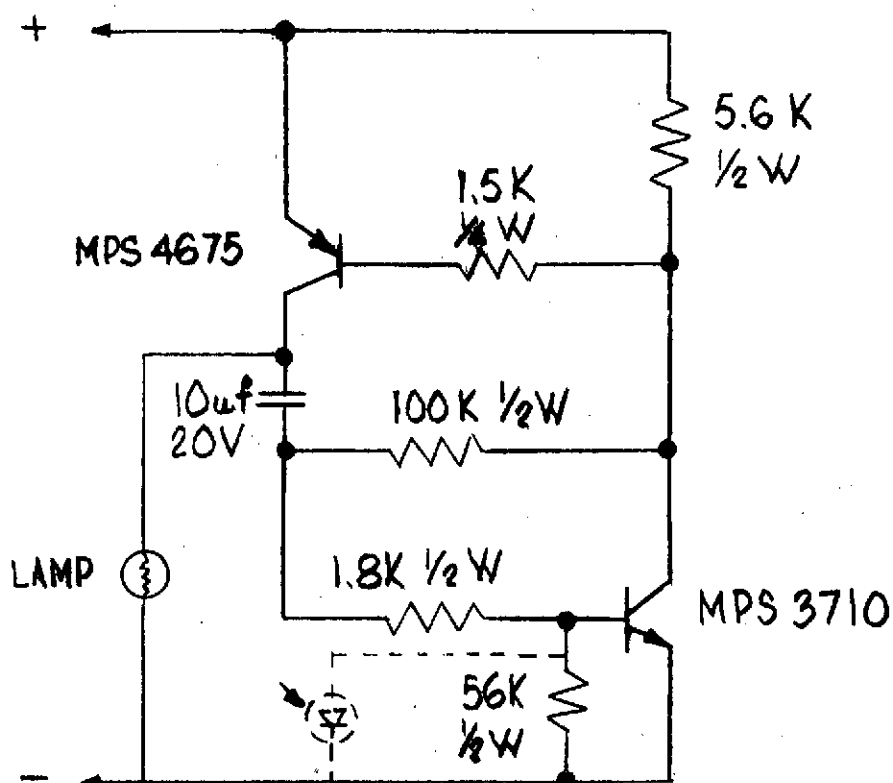
ANNUAL MEAN SOLAR RADIATION PER DAY IN THE U.S.
IS 387 LANGLEYS

THE SOLAR ARRAY WILL DELIVER 1.12 AH/DAY TO THE BATTERY
BASED ON ABOVE VALUES.

BATTERY CAPACITY - 20 AH

SYSTEM RESERVE $20 \text{ AH} \div 588 \text{ AH/DAY} = 34 \text{ DAYS}$

PREPARED BY: LANGAN	spectrolab A Division of tektron Inc.	PAGE NO. OF
CHECKED BY:		Job No. REPORT NO.
DATE: 9-26-78	TITLE FLASHER SCHEMATIC	MODEL NO.



Solar Water Pump System
(Code 1 IC)

1.0 DESCRIPTION OF THE SYSTEM

The system consists of an electric motor operating on direct current in conjunction with a solar power supply to drive a pump for irrigation in remote areas and underdeveloped countries. The pumping system is designed to operate where the water table is relatively high. A considerable amount of water is required for proper crop irrigation. At 10 gallons per minute pumping on the average of 10 hours per day, the system will deliver approximately .44 inches of water over a one half acre area each day. These are the specifications to which the solar water pump system was designed.

2.0 DESIGN CONSIDERATION

Standard, available off-the-shelf components were specified where possible to enhance the practicability and make prototype development feasible. Following is a brief discussion of component designs:

1. The weight attribute of the solar array make portability a problem. Further design efforts may include compact packaging (fold-out array), telescopic legs, etc. for transporting on a pick-up truck.
2. The pump motor operates off direct current and will deliver 10 gallons per minute with a total head of approximately 36 feet. This includes pipe, motor, shaft and pump impeller losses.
3. The pump and motor are housed in a rain tight box with a hinged lid.

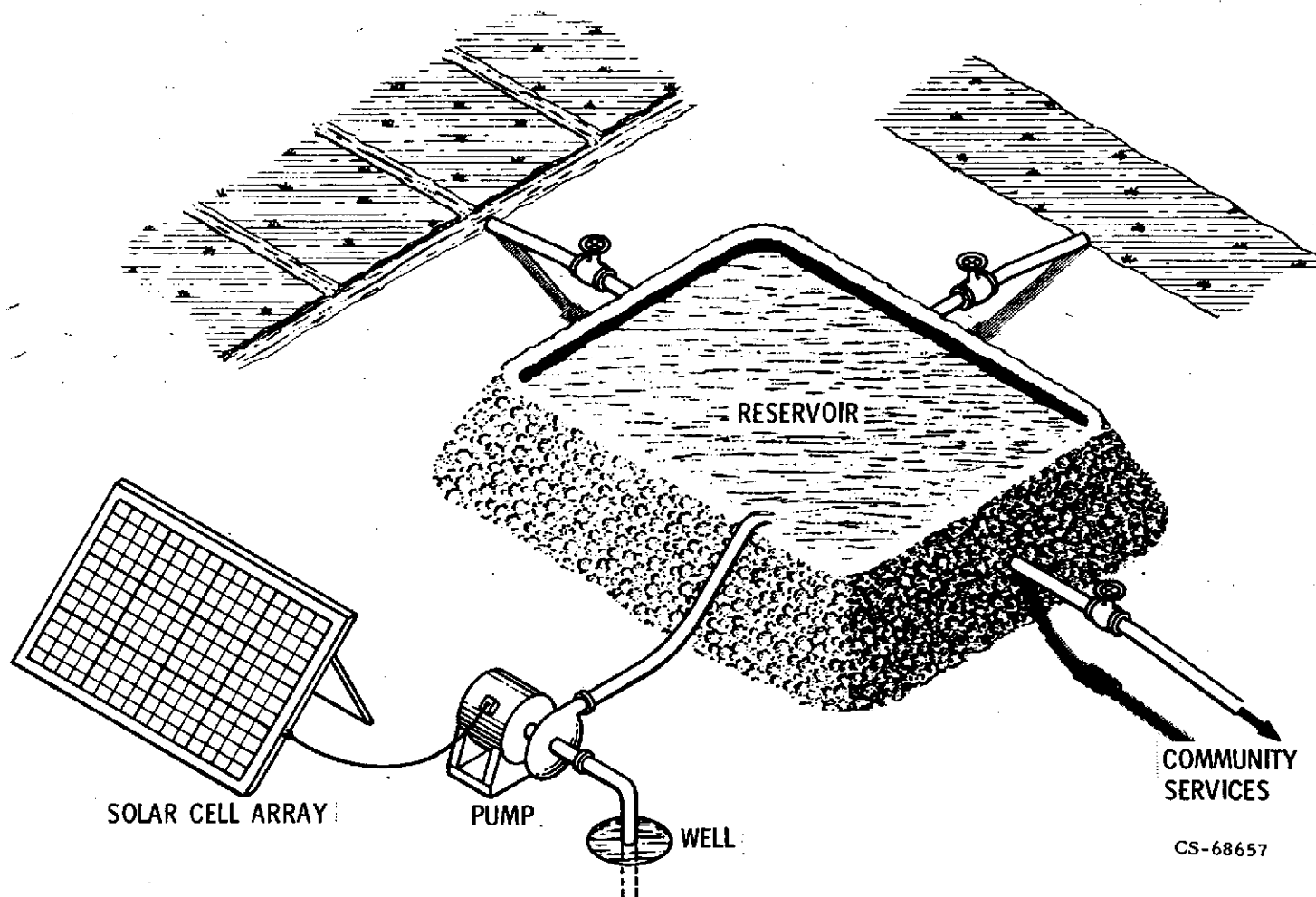
3.0 COSTS

Solar cells	\$576.00
Extrusion and frame	223.68
Pump	69.00
Pump box, cable, connector, etc.	30.00
Labor and G and A	<u>315.65</u>
Solar water pump cost	\$1,214.33

4.0 CONCLUSIONS AND RECOMMENDATIONS

1. The cost of the solar water pump system appears to be prohibitive as a stand alone irrigation system. Alternatives include:
 - (a) Specifying other than irrigation as the primary application for the solar water pump system. A system that includes a water purifier and storage tank for personal consumption and livestock watering would significantly reduce the array size.
 - (b) Using the solar power system as the primary power source for applications in addition to pumping water.
2. Additional consideration should be given to designing a water pump specifically for use with a solar array. A more efficient pump would result in a smaller load, thus, a smaller power supply.
3. A prototype model should be built to prove the design. The volume of water over time should be reduced to minimize the cost of the pilot system.

WATER PUMP SYSTEM



7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Standard Module Concept

Analysis of research data gathered during the program indicated the desirability of a standard solar array module which could be used in a number of different applications such as communications, environmental monitoring stations, etc. The basic specifications for such a module can be inferred from an analysis of a survey of communication engineers.

The direct mail survey referenced above yielded the following data concerning power supply requirements for remote communications stations:

- (a) 5.9% specified average requirements of 10 watts or less
- (b) 10.3% specified 10 - 20 watts
- (c) 30.9% specified 20 - 100 watts
- (d) 35.3% specified 100 - 1000 watts
- (e) 17.6% specified 1000 watts or more

Based on these figures, a feasible average power output specification for a practical size solar array, and the probable size of the market for such a module, were established.

Assuming that the standard module would have a power output of 100 watts or less, this could satisfy the requirements of $5.9 + 10.3 + 30.9 = 47.1\%$, or nearly one-half of the remote communications stations. Furthermore, since the largest category of respondents whose requirements are less than 100 watts were in the 20 - 100 watt range, it was assumed that approximately one-half of the 30.9% in that category would desire a unit with a power capacity equal to the average of that range. Thus,

$\frac{30.9\%}{2}$ require a power capacity of $\frac{100-20}{2}$ watts, or
15.5% require a power capacity of 40 watts.

The potential market for a 40-watt solar power supply in this application therefore

would be 5.9% (10 watts or less) plus 10.3% (10-20 watts) plus 15.5% (average of the 20-100 watt group) = 31.7% of the total.

A second correlation was made between the responses to a question in the communications survey concerning price sensitivity. The question was: "Excluding the storage devices, what price per watt would you be willing to spend for a solar powered generator?"

- (a) 52.0% replied \$1 to \$10
- (b) 14.3% replied \$10 to \$20
- (c) 7.2% replied \$20 to \$30
- (d) 7.2% replied \$30 to \$40
- (e) 4.8% replied \$40 to \$50
- (f) 14.5% replied \$50 to \$60

It is interesting to note that the high percentage of respondents who would be willing to pay \$50 to \$60 correlated with the percentage who had prior knowledge of solar cells and therefore presumably were aware of present costs.

From the above listing, the total percentage of respondents expecting to pay \$20 or more per watt for solar power is

$$7.2 + 7.2 + 4.8 + 14.5 = 33.7\%$$

This figure correlates closely with 31.7% requiring 40 watts or less power, as previously computed.

From the above analysis, it was concluded that a 40-watt solar power module was worthy of consideration. Also, the minimum price of \$20 per watt is feasible from a manufacturing point of view, although \$40 per watt was used initially in the risk analysis computations.

It should be emphasized that the standard module concept was not considered as a substitute or alternative to solar cell products specifically designed for particular markets, but simply as another candidate which would have wide application.

7.2 Conclusions

As a result of the study program to identify, catalog, evaluate and develop design concepts for terrestrial applications of solar cells, the following general conclusions have been drawn:

1. There are many potentially profitable applications for solar cells, the great majority of which involve the use of a solar array in combination with rechargeable battery and voltage regulator.
2. There is a sufficiently large market for these systems at the projected \$5/watt price to warrant the required investment in engineering, product development, automated production equipment, field testing and marketing.
3. There are a significant number of government programs under way or in the planning stage that could incorporate solar cell technology.
4. The near term future usage of solar cells will depend largely upon a comprehensive education program involving potential users.

7.3 Recommendations

Based on the conclusions outlined in section 7.2 above, the following recommendations for future action are offered:

1. A nationwide program, preferably under government sponsorship, to educate potential users in the principles and potential applications of solar cell technology.

Analysis of the data obtained during the program revealed a surprising lack of knowledge of solar cell technology among technical as well as nontechnical people. For example, in a survey of forestry officials, including communications specialists, engineers, and top management, only 15% were reasonably or very familiar with solar cells. Over 70% were only somewhat or vaguely familiar, and 12% were totally unfamiliar.

This pattern, with the exception of meteorologists where the level of familiarity was significantly higher, was prevalent in all the fields studied, including pollution researchers.

The conclusion to be drawn is that there is a strong need for educating people about solar cell technology and its merits as applied to specific fields. The probability of successful new applications will be greatly enhanced if information regarding its potential uses and benefits can be imparted to responsible officials in terms that they can relate to.

Our recommendation therefore is that a program be undertaken to study and evaluate all conceivable methods of information transfer in the area of interest. This study should cover audio/visual techniques, news releases, space advertising, newspaper feature articles, trade journal articles, TV documentaries, direct mail promotions, lectures and seminars, application notes, textbooks, demonstrations, mobile displays, public announcements, press conferences, trade show participation, lab experiments and demonstration materials for schools, and research and data processing services. Recommendations would then be made as to the most practical and cost-effective methods, and materials developed to illustrate the concepts.

2. A follow-on study program, similar to the one just completed, with the specific objective of identifying and evaluating present and future government-sponsored programs which might incorporate solar cell technology.

Of the 66 potential applications cataloged during this study, well over half are either partially or completely related to government owned and/or operated

equipment. . Because of the limited time and scope of the program, and its stated objectives, it was not possible to fully evaluate the potential government applications for solar cells.

A comprehensive search should be made among all government agencies with regard to present and future programs which might utilize solar cells. State and local agencies should be contacted as well as Federal. In addition to identifying specific programs, it should be possible also to catalog some specific present and future needs of government which might lead to new and as yet unknown applications for solar cells. The results of the present program should be disseminated among the various government agencies to alert cognizant personnel as to the potential uses of solar cells.

It is our opinion that such a follow-on program would serve to broaden the market base for solar cells, with all the attendant benefits thereof.

3. A follow-on study and design program to develop a balanced set of solar cell applications in three major areas: urban, rural, and underdeveloped countries.

One objective of this program was to find solar cell applications which have the potential for improving the "quality of life". It is our belief that this objective can be furthered by means of a program that would give equal attention to the needs of urban and rural communities, and underdeveloped countries. It is possible that a single solar cell application can be found which would help to improve the quality of life in all three of these areas; more likely, three separate applications would be required. In any event, a thorough study should be made of the most pressing needs in each of the three areas as they relate to electrical power, followed by a design study and prototype development program, culminating in an operating prototype system for each area.

Because of the scope of such a program, and the range of interest among various agencies, it is suggested that a co-sponsorship arrangement might be worked out among, for example, NASA (program management), HEW (urban), Department of Agriculture (rural), and the State Department (underdeveloped countries).